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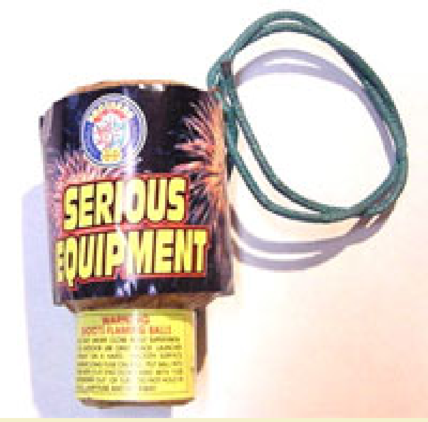
Volume 4, Issue 2

AUTOPSY

1-3/4" Brothers Class C Canister Shell

by Michael Fales



Manufacturer:	*Brothers*
Shell Weight:	*58 grams*
Lift Charge:	*3.9 grams 2Fg BP*
Burst Charge:	*7.5g loose KP + 11g KP on hulls*
Shell Type:	*1-3/4" oriental canister*
Time Fuse:	*Single Chinese, 1.5 second delay time*
Shell O.D.:	*1-3/4"*
Shell Height:	*1-7/8"*
Wall Thickness:	*1/8"*
Cup Set:	*7/8" deep X 1-1/2" I.D. X 1/16" wall thickness*
Star Type:	*18.6 grams of Dragon Egg clustered stars*
Mortar Size:	*1-15/16" I.D. X 14" tall X 1/4" wall thickness, mounted on polymer base and held in place with a nail*

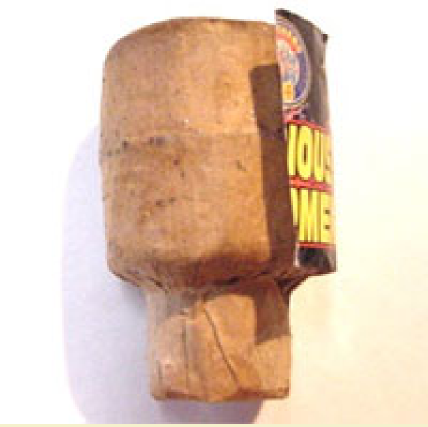


Figure 2: Lift cup pasted onto shell with a turn of light weight kraft.

Canister Design Scales Well:
Unlike Italian style canister shells, where the methods of construction change considerably as the shell size becomes very small or very large, the Chinese method of building canister shaped shells changes very little with size. Ball shells share this same advantage, and really the Chinese method of canister shell construction is basically the same as ball shell construction with the exception that cylindrical shaped hemis are used instead of spherical hemis. For an example of a larger shell constructed in the same method shown here, see the previous autopsy of the 5" Lidu Crossette Canister Shell.

As is common with most class C items, the label is decorated with beautiful big breaks. The names given to Brothers products are often artifacts taken from American culture that come across as humorous attempts at marketing across a vast culture gap. This one seems to be targeting the consumer's desire out-do his neighbors on the block with the title "serious equipment". The label only shows the Brothers logo and which end to place up in the mortar. Nowhere on the shell does it describe the effect you might expect!

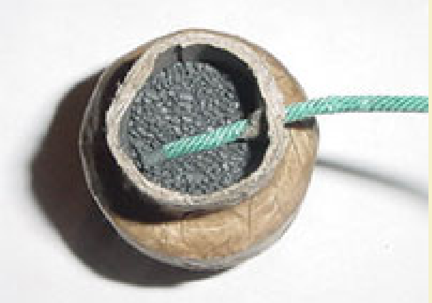


Figure 3: Lift cup filled with 3.9g of 2Fg.

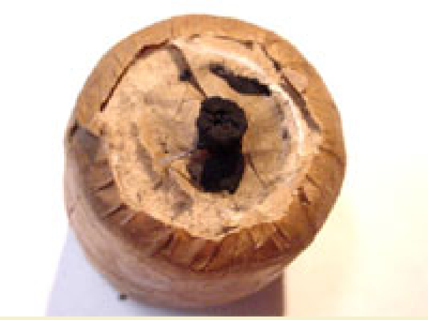


Figure 4: Slurry primed chinese fuse.

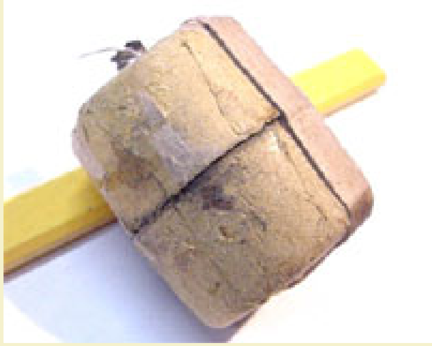


Figure 5: Cup set pasted in with strips.

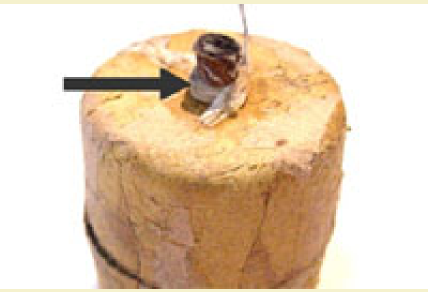


Figure 6: Gampi tissue fire block around time fuse.

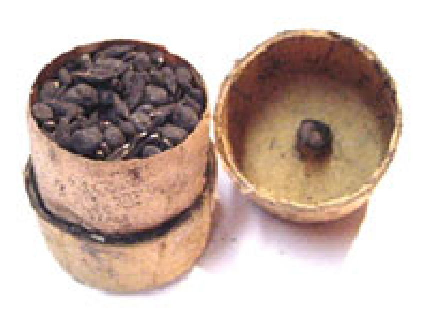


Figure 2 reveals a single layer of thin pasted kraft starting at the top edge of the shell and reaching down on to the lift cup where it was crimped down and held in place with another single layer band of pasted kraft paper.

The lift cup is a thin paper tube 1” in diameter and 7/8” in height with a 1/16” wall. It is glued to the bottom of the shell and held in place by the previously mentioned final paste layer. A hole is pierced through the side of the lift cup to accept the fast visco type fuse used as the leader. A small piece of clear tape is placed over the leader at this hole and half way up the shell. The lift is 3.9 grams of 2Fg size BP and is kept in place by a square of kraft paper pasted over the bottom of the lift cup which is then covered by another band of paper and the warning label.

The time fuse is placed in the center bottom of the shell just as a regular ball shell would be constructed. It is cut straight and slurry primed with black powder. A small wrap of pasted gampi tissue is wrapped around the base of the time fuse, appearing to protect against lift gases blowing around the time fuse.

Removing the thin outer paste layer revels that the shell is pasted in with vertical strips much like a ball shell, as seen in Figure 5. Approximately 6 layers of kraft paper are used to paste in two strawboard “hemi-cylinders”. The strips are approximately 1” wide and reach from the time fuse at bottom center to slightly past the top center of the shell. These strips were not tapered at the ends, so they created a slight build up at the top and bottom centers of the shell. A small loop of string is pasted into the last layer for supporting the fast visco leader while loading the shell.

Separating the two strawboard hemis reveals an innovative loading procedure. A thin cardboard liner the height of the shell is first placed inside the one of the hemis, most likely the time fused side. The contents of the break are then dumped in to fill the entire height of the shell. The other hemi-cylinder cup is fitted onto the top and held in place with a single band of pasted kraft around the equator of the shell. One can imagine a worker rapidly scooping the shell contents from a large tub of pre-mixed break/stars, closing it and handing it off to the next worker to paste in.

The time fuse is a total of ¾” long and cut at an angle on the inside of the shell only giving about 5/8” length before igniting the inside of the shell. Both ends of the time fuse are slurry primed. The contents of the shell were not placed in any particular order as is common with class C type shells. Stars, KP coated rice hulls and loose KP powder were mixed throughout and filled the shell entirely. The stars are irregularly shaped ranging in size from 3/16” to 1/4” and contain dragon egg type microstars. They appear to be charcoal star formula coated on dragon eggs that are rolled and allowed to form into small groups of dragon egg bursts. Each star contains around 2 to 5 dragon egg bursts.

The break charge found here is an interesting mixture that has also been found in other smaller shells as well. The combination of coated rice hulls and a fine grained powder mixed in loosely among them seems to add more kick than either one of these

Figure 7: Liner with aggragate mixture of stars, KP hulls and loose granulated KP powder.

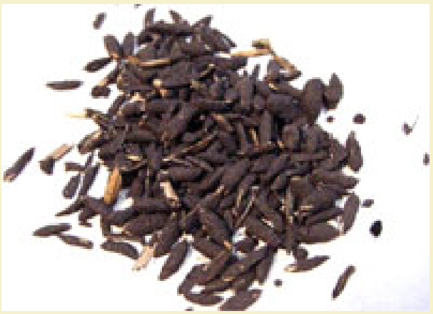


Figure 8: KP coated rice hulls.

Figure 9: Finely granulated KP burst charge.

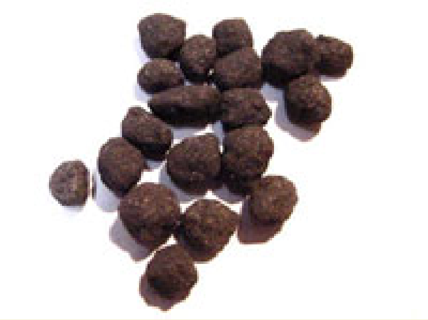


Figure 10: Clusters of small dragon egg micro stars rolled into globs.

charges would produce alone. The hulls most likely serve to fill the extra space and keep the loose powder from caking, while the fine grained powder increases the burn rate by exposing more surface area. The use of KP is somewhat surprising and suggests that this charge does not need all that much confinement to reach the pressure where its burn rate ramps up to a point equal to the strength of H3. Shimizu notes that KP is inadequate for shells under 4" in size, but here we find it being used in a tiny 1-3/4" shell!

This shell breaks in a hard pattern that is not perfectly round but certainly better than par for Class C shells of this size. The weak spot at the center of the shell resulting from the seam where the two hemis meet may play a key role in the break pattern. This insures that the shell will break at the center point, thus removing the risk of one or both ends blowing out and creating an undesirable spray of stars in one direction (a common problem with small canister shells). The avoidance of flash as a break charge shows Brothers concern for the quality of their effects, sparing the viewers the annoying retina spotting caused by the flash broke shells that are common in this size.

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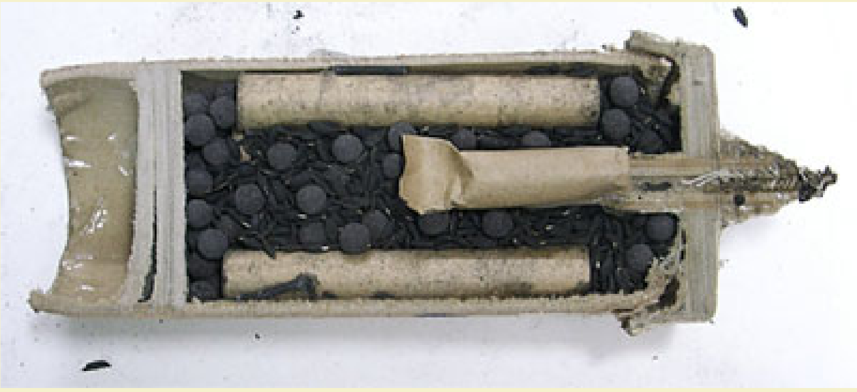
Volume 3, Issue 3

AUTOPSY

3" Tourbillion w/Report and Red Stars

Manufacturer:	*Vulcan*
Shell Weight:	*379g*
Lift Charge:	*50g 4Fg black powder*
Outer Burst:	*54 g KP on rice hulls*
Flash Bag:	*2g slow flash (dirty flash)*
Stars:	*9/32" dia. round stars*
Tourbillions:	*3.75" long, 9/16" O.D., 3/8" I.D.*
Casing:	*Spiral wound, 6.5" long, 2.5" O.D., 1/8" wall*
Time Fuse:	*Single chinese time fuse, 2.5 sec delay time*



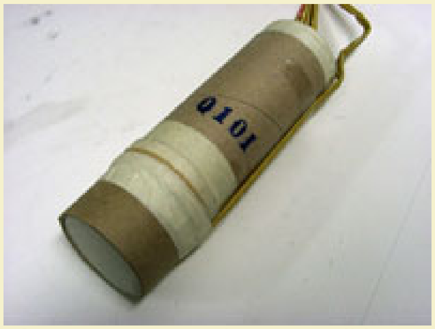


Figure 1: No pasting, no spiking, just a simple spiral wound tube plugged at both ends.

Autopsy Report:
This 3" shell is part of a new line of canister shells from Vulcan that are now on the market. Some of the internal inserts are made in Germany, but the shell itself is assembled in China.

Vulcan's shells have been pretty high quality lately, with each shell wrapped in a plastic bag with a moisture absorption packet. Their leaders are also coated in a plastic similar to packing tape, as is the fuse cap, making them extremely resistant to moisture. If you fire shows in a damp climate or rainy season such as in Florida, then you may find Vulcan's moisture resistant packing reduces the number of shells left in the guns at the end of a show during which rain occured sometime after setup.

On the outside this shell looks like your typical Italian style 3" shell, although at a length of 8" it is a bit on the long side. A 40 weight paper covers the outside, which is folded and taped down on the bottom and tied off around the leader on the top. The leader runs down the side into a stiff cardboard lift cup at the bottom.

Removing the outer wrap reveals the surprise shown in Figure 1, which is a shell completely devoid of any spiking twine or pasted paper whatsoever! The liberal use of masking tape would make old Italian shell builders wince, and I'm sure the Orientals who were assigned to assemble these shells found them quite peculiar as well!

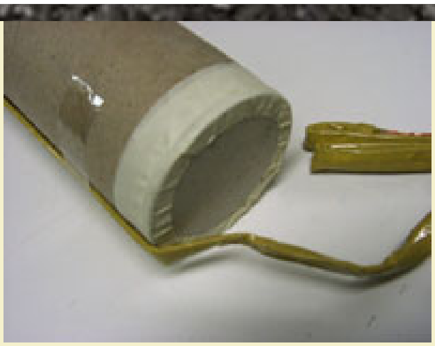


Figure 2: Outer disk held on with masking tape.

This shell is basically a spiral wound tube with a triple disked plug on both ends, as seen in the cutaway above. The top disk taped onto the shell in Figure 2 probably adds nothing to the burst containment and is only there to cover the void beneath it.

Figure 3 shows how the end is plugged, which is really more substantial than it might first appear. A liberal amount of glue covers the tube wall above the disk, which is a laminated set of 3 disks that total 1/2" in thickness. The glue braces the disk at the edges and prevents it from blowing out easily. The non-brittle nature of the dried white glue makes it ideal for this purpose.

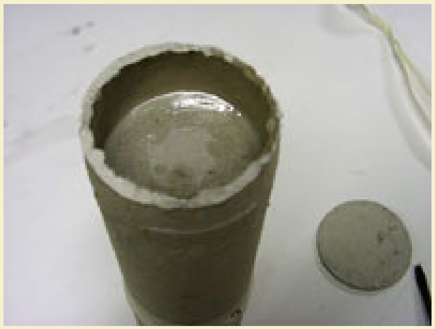


Figure 3: Triple disk inner plug held in place with lots of white glue.

Figure 4 shows the lift cup removed from the shell, which contains 50g of fine 4Fg type black powder in a plastic baggie tapped onto the shell leader. Note this is roughly twice as much as the ounce per pound rule would dictate for traditional canister shells.

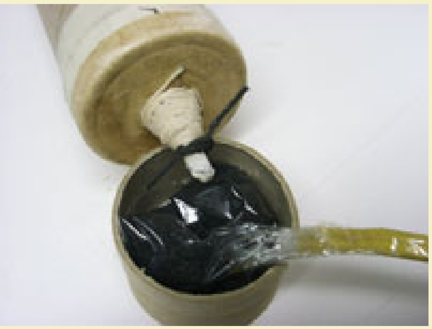


Figure 4: Bottom fused with plastic lift bag. Note the amount of glued string wrapped around the time fuse base.

The plug on the bottom fused end of the shell was substantially less secured, and it surprises me that the contents of this shell don't just blow out the bottom. A thick cap is fitted with three disks like the other side, but the cap is just glued onto the end of the tube and was easily pried off with a screwdriver.

Figure 5 shows the details of the interesting fusing method devised for this shell. A piece of regular Chinese time fuse is half covered in masking tape and then inserted half way into a spolette tube that was probably first glued into the shell cap. Cotton string soaked in glue is then used to build up a conical seal around the time fuse and the tube, which prevents the lift gases from leaking around them and also insures that they don't get blown into the shell. The time fuse is cross matched through the masking tape, then a piece of fast burning visco coated with black powder is threaded through and tied around the time fuse in a knot to keep it from falling out during lift.

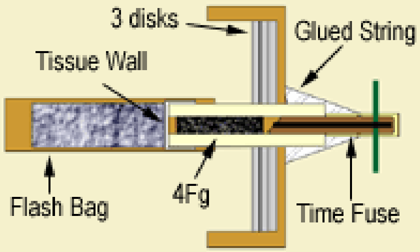


Figure 5: Details of time fuse and flash bag components.

On the internal passfire side of the fuse, the tube is filled with 4Fg black powder and closed with a sheet of tissue paper. A few turns of light kraft are used to form a flash bag that gets taped onto the tube. The bag is filled with 2g of a slow burning flash (no thump when lit) and pinched closed.

Note that this method of using time fuse and a spolette tube combined would allow the use of very short pieces of time fuse that normally couldn't reach from the inside of the shell to the outside if used in the typical way. This is one way time fuse could be adapted for use in multi-break shells with short timing between breaks. While it is more work than simply ramming a spolette, the risks of blow through would be less on short timings.

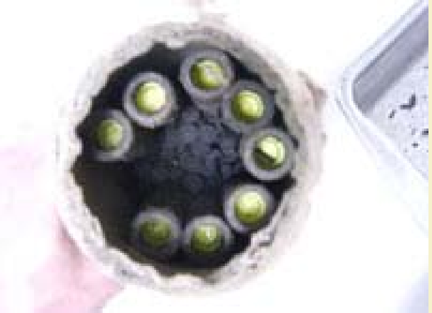


Figure 6: Fused end cap removed, looking down at the tourbillions. Note the yellow plastic end plugs.

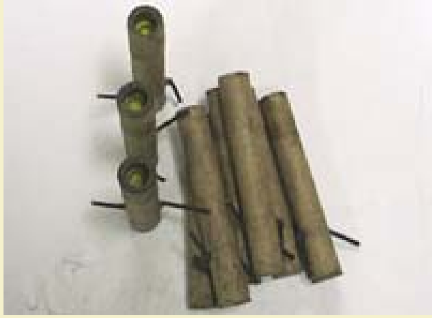


Figure 7: Tourbillions "crossmatched" with black powder coated fast visco.

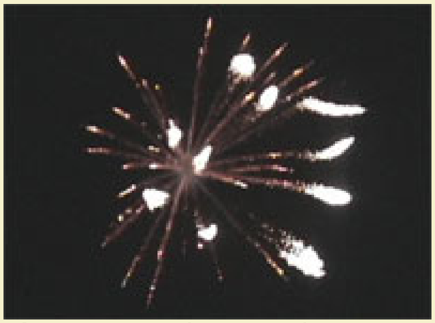


Figure 8: Break pattern is surprisingly round with no signs of blowing out one end.

Figure 6 shows the tourbillions lining the wall of the canister as expected. A break charge of KP on Chinese rice hulls is mixed about 50/50 with the stars that filled the rest of the shell.

The yellow plastic end plugs used to plug the tourbillions show tell-tale signs of European manufacturing. The tourbillions were also fused completely through the casing with a fuse running through like cross match. It would seem that two opposing jet streams would not allow the tourbillion to do much spinning, but it works none the less.

After seeing this construction method, no doubt considered a hack by any self respecting Italian shell builder, it is surprising just how well the shell actually breaks. Figure 8 shows the shell in action, which looks pretty good for such a small shell! But like any low confinement break system, the shell must be slammed hard by an energetic break for it to work. This requirement prevents this technique from being used to produce a softer, denser color break of equal symmetry.

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Volume 2, Issue 8

AUTOPSY

4" Canister: Green w/strobe reports

Manufacturer:	*Lidu*
Shell Weight:	*617g*
Lift Charge:	*40g 3FA black powder*
Burst Charge 1:	*88g KP on Hulls, 8:1*
Burst Charge 2:	*30g granulated "dirty" flash*
Stars:	*1/2" dia. round stars*
Inserts:	*21 inserts, 1-3/8" long x 1/2" O.D. x 3/8" I.D.*
Shell Type:	*4" paper canister*
Time Fuse:	*Chinese time fuse, 4 sec delay time*

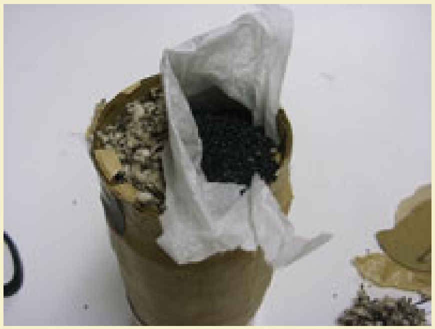

Figure 1: Lift charge contianed in paper liner surrounded by ground cotton seed.

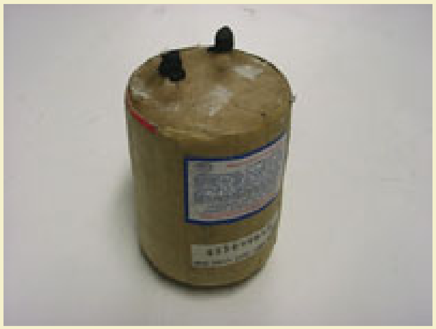

Figure 2: Strip pasted can with slurry primed, dual piped time fuse.

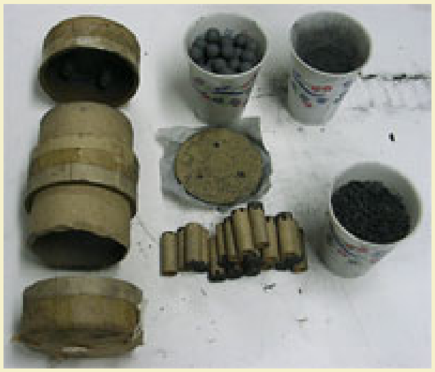

Figure 3: Disassembled shell with all components.

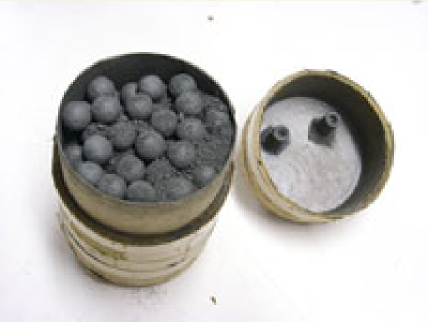

Figure 4: Bottom cap removed (time fuse end) to reveal star compartment with granulated flash break.

Autopsy Report:
I fully expected that this shell would be very similar to the 5" Lidu canister shell that was examined back in April. This shell still employed the same method of packaging the lift as other Lidu canister shells, with a tissue bag holding the powder around the time fuses while the extra space was filled in with ground cotton seed (see Figure 1). This shell was also pasted using strips of paper instead of a rolled sheet as is common in the Italian method of canister shell construction. Unlike Lidu's ball shells, only about 3 or 4 layers of about 40 weight paper strips are used to paste in this shell.

While the 5" crosette canister shell made by this same manufacturer used a pair of cylindrical cups to form the inner case, this shell features a spacer between a similar set of cups that are used as end caps. A single turn of chipboard is rolled on a former,

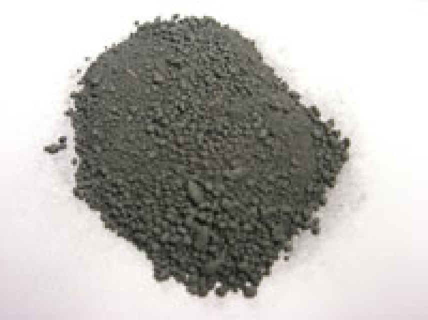

Figure 5: Dark, granulated flash of moderate burning speed used to break the star portion of the shell.

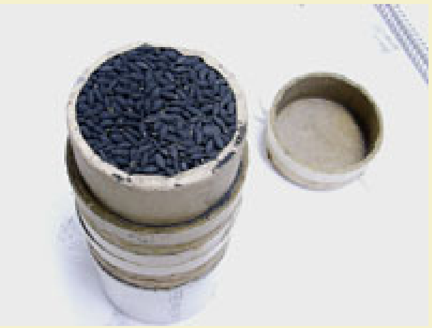

Figure 6: Top cap removed reveals KP burst charge packed around inserts.

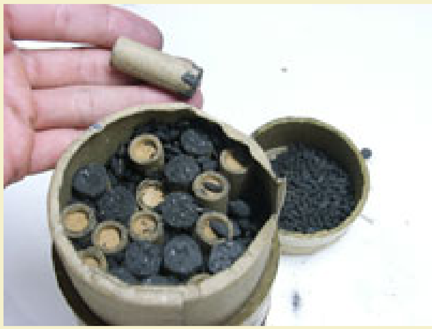

Figure 7: Inserts completely fill bottom compartment, with prime end randomly oriented.

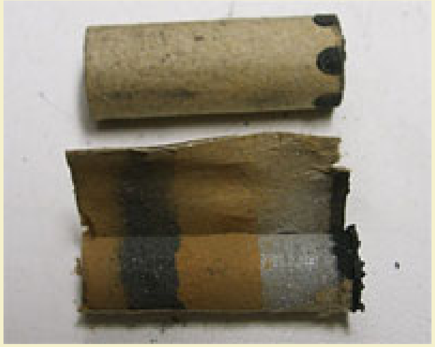

Figure 8: Insert charge from left to right: clay, flash, clay, white strobe and prime.

then the central spacer is rolled on top of this until it is equal to the O.D. of the cup set (see Figure 3). The end caps can then slide over the chipboard sleeve and seat flush with the central spacer. The two seams at each end are then secured with a band of tape prior to pasting. This design allows the height of the shell to be adjusted for different contents while still using one size of 4" cups for all 4" shells. The case is similar in construction to mailing tubes, only the body is parallel wound and the two ends are punched in a press.

The shell contents were divided into two distinct compartments, separated by a chipboard disk with three passfire holes punched in it. A piece of tissue paper was placed behind this disk in order to prevent the contents of one compartment from migrating into the other. This disk can be seen at the center of Figure 3.

The compartment containing the stars, seen in Figure 4, was fully loaded with 1/2" stars and a partially granulated flash mixed in between them as the burst charge. This burst charge, shown in Figure 5, contained a wide range of particle size, from roughly 2FA all the way down to fine powder. This charge looked as though it may contain antimony, and burned slower than typical flash used in salutes.

The second compartment, shown in Figure 6 and 7, contained 21 inserts that filled most of the space. A burst charge of KP on rice hulls was packed around them, mostly above and below the inserts. Each insert was primed with a slurry prime dipped in 4FA on one end. The orientation of the primed end was random rather than directed to the center of the shell. With the time fuse protruding only about an inch into the opposite end of the shell, there appears to be a high degree of confidence that the shell will contain the fire long enough to get through the divider and reach the primed inserts located at the opposite end.

The construction of the inserts themselves is an interesting item for examination. The primed end ignites a white strobe composition that seems to be only moderately pressed on top of a fused clay bulkhead that encloses a flash charge between another clay plug. It would appear that the flash charge was pressed along with the clay plugs, but not as forcefully as a rocket would be. The fuse leading through the central plug, which is a piece of small diameter visco type fuse, also appears to have been pressed along with the plug itself, rather than inserted later. Due to a noticeable bulge in the center plug, it is my estimation that the plug and fuse were pressed together as the first charge. The flash and end plug were then lightly pressed into one end while the strobe comp was also lightly pressed into the other end. The distance on both sides of the center plug are equal, which would eliminate the need to orient the insert depending on which effect was being pressed.

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AUTOPSY

4" Peanut Shell

Manufacturer: *Unknown*
Shell #1 Weight: *737 grams*
Shell #2 Weight: *277 grams*
Lift Charge: *63 grams 3FA BP*
Burst Charge: *66 grams KP on rice hulls*
Shell Type: *4" Chinese ball shells*
Time Fuse: *Double Chinese, 3 second delay time*
Star Type: *3/8" fast burning color stars*

Performance: *While it is more typical for the second shell in a peanut shell to break a few seconds after the first shell, both shells break at the same time in this case. The first shell is a color break while the second shell is a salute. The color break maintained good round symmetry, although tended to burn out sooner than would be desired. The salute, which breaks at the same time as the shell, was rather unimpressive for a 4" salute and no louder than the color shell break.*

Construction:
Peanut shells are really nothing more than a pre-packaged method of "double loading" ball shells. For those not familiar with the practice of double loading, the technique involves loading a ball shell into the mortar in the standard way, then clipping the leader short on a second ball shell, cutting back the paper to expose the raw black match, then dropping the second shell down on top of the first. When the first shell fires, the second shell fires at the same time and they both break simultaneously at the proper height. While some frown upon this method out of unsubstantiated fears, the technique is most often used as a way to double the number of finale shells fired at the end of a show without doubling the rack count.

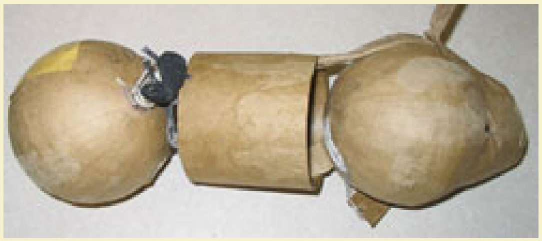

Figure 2: Quickmatch passfire used to ignite 2nd shell.

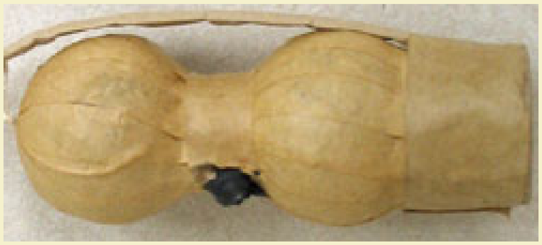

Figure 3: Alternate passfire method using exposed prime on 2nd shell.

Peanut shells are really not multi-break shells in the true sense, since both shells ignite upon lift rather than the break of one shell igniting the time fuse of the next shell. This is why I consider it just a fancy way of double loading a shell. The main advantage to a peanut shell is that the manufacturer can control the delay between the two shell breaks, thus making ball shell effects such as color break with delayed bottom shot, simultaneous color breaks, two break color shell etc.

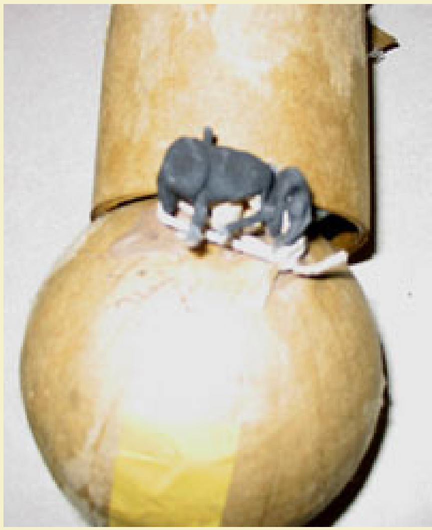

Figure 4: Thick prime on upper shell.

The 4" peanut examined here uses a quickmatch leader to pass fire from the lift bag to the primed time fuse on the second shell. Figure 2 shows the passfire running up the side of the bottom shell into the cardboard collar that connects the two shells. An alternate method of making sure the second shell ignites is to expose the primed time fuse to the outside of the shell, which can be seen in the 2" Lidu peanut shell depicted in Figure 3. This exposed prime will easily take fire from the flame envelope rushing past the shell during lift. The disadvantage to this simpler method is the accidental ignition hazard created from the exposed prime.

Figure 4 shows a cardboard collar that is used to connect the two 4" shells together, giving them the tell-tale peanut look. This collar was only loosely connected using tape and was clearly intended to break apart on lift so that the two shells will drift on separate paths. This was likely done to prevent the scenario where the salute breaks before or exactly at the same time as the color break shell, which would likely blow the color break pattern out of symmetry at such a close range. A better effect would have been to put a longer delay on the salute shell, thus giving a color break followed by a delayed "bottom shot" effect.

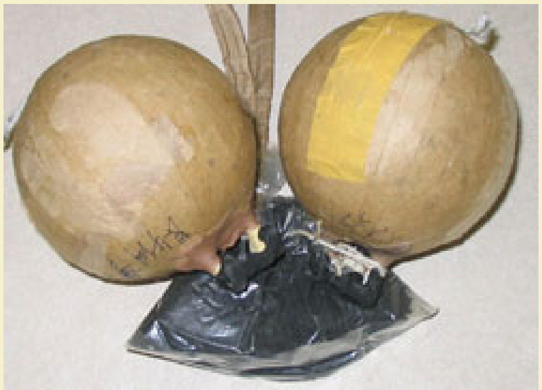

Figure 5: Both shells shown with plastic lift bag.

Note in Figure 5 that the bottom shell has a hard, reddish sealant around the time fuses to help prevent flower potting. Peanut shells are subjected to greater pressures on the bottom shell due to the increased weight and length of the overall shell, so this extra precaution has been taken to prevent gas leaking around the fuse joint.

Both shells were double fused and heavily primed on the time fuses, but cross matching was not used on either end. Figure 6 shows the small rice paper bags of black powder grains fastened to the ends of each time fuse, used to insure a rapid spread of fire once the time fuses burn through. Note the red sealant around the base of both time fuses as an additional gas leak precaution.

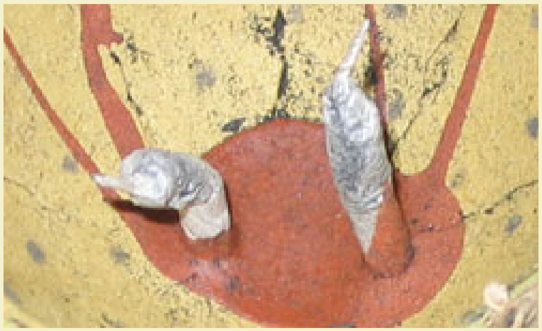

Figure 6: Small BP burst bags fastened to time fuses.

The color break shell was loaded with 3/8" stars followed by rice paper liner and KP rice hulls in the standard configuration. Like all Chinese shells that have been autopsied here, the burst and stars seem to have been loaded in a damp state and all components tended to stick together into clumps when removed. The black spots where the stars contact the casing in Figure 6 is further evidence that they were damp upon insertion. Since this practice seems to be used by all the various manufacturers, it probably plays a key role in achieving good burst patterns.

Volume 3, Issue 4

AUTOPSY

4" Red Falling Leaves

Manufacturer:	*Vulcan*
Shell Weight:	*245g*
Lift Charge:	*53g 4Fg black powder*
Burst Charge:	*85g KP on rice hulls*
Stars:	*80 leaves 2-1/2" x 1-3/8"*
Casing:	*Chinese hemi, 3-3/8" I.D., 1/8" wall*
Time Fuse:	*Double piped chinese time fuse, 3 sec delay*

Autopsy Report:

This is another product from Vulcan that shows fine craftsmanship. Again they are using the plastic wrapped shell leaders that come standard on Vulcan shells (they also sell just the leaders separate if any wholesalers are interested in getting your hands on some).

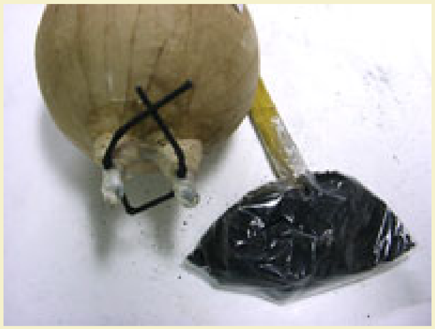

Figure 1: Bagged lift with plastic coated leader.

Figure 1 shows that the shell leader is taped to the plastic lift bag, not tied in. It has been my own experience that tying in the leader tends to choke it off at the tie point, making a dud more likely if your black match has a weak spot or you are only using one strand. Keeping the pipe fully open all the way into the lift will reduce the chances of a hang fire or dud.

Also visible in Figure 1 are the dual piped time fuses. Note that one piece of cross match was used to fuse both fuses, which is a subtle innovation that was probably done to reduce the step of having to pick up a second piece of match in the assembly process. The cross match used is actually a thin diameter type of rapid burning visco that has been coated with black powder slurry on the outside to aid with side ignition.

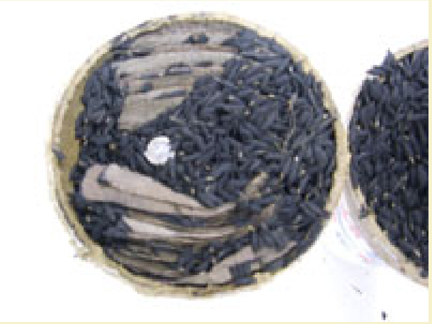

Figure 2: Shell contents.

Like most shells from China, this shell was initially constructed with hollow tubes that are later plugged with the actual timing elements. This is done so that the shell contents can be loaded in a damp state and then dried following the pasting operation. The tubes allow the moisture to escape from the inside of the shell during drying, then they are later plugged with the time fuse. The large wrapping of string around the base of both time fuses helps prevent gas leaks around the edges of the inserted fuse, which would result in a flower pot on lift.

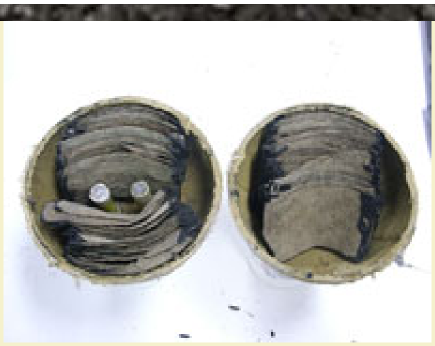

Figure 3: Leaves with burst charge removed.

The paste wrap on this shell was remarkably thin, about two layers of 40lb kraft. The intent is to pop the shell open and let the burning leaves drop out as a condensed clump, after which they drift apart as they fall.

Figure 2 shows how the burst was distributed among the leave stars. A total of 80 leaves were packed into the shell, with a stack of 40 fitting into each hemisphere.

The leaves themselves were nothing more than rectangular pieces of 30lb kraft paper that had been coated with a slow burning color composition and primed on both ends with black powder. This was probably accomplished by dunking the leaves into a tray full of composition watered down to a slurry form.

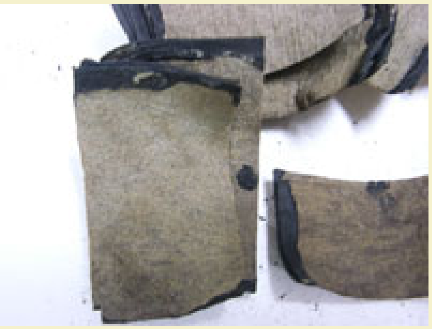

Figure 4: Closeup of a leave star.

Shimizu describes the construction of the falling leaves effect using a special type of gampi tissue paper that has a good wet strength, making it unlikely to tear during manufacture. However, no such paper was used in this shell. Just plain old brown kraft paper.

The leave stars were rather stiff, which indicates that they must have been loaded in a damp state in order to get them to conform to the shape of the shell. The fact that many of them were stuck to each other also suggested a damp state when loaded.

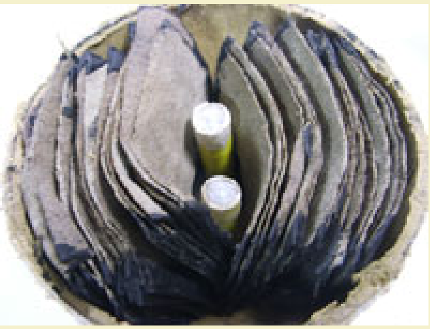

Figure 5: Forty leaves packed in each hemi.

The burn rate of the leaves varied greatly depending on how much comp was on them. Some of the leaves would not even stay lit while burning on the ground, but the added oxygen present when falling through the air is likely to correct this problem.

A slow burning lance composition would be a good starting point for anyone whishing to make their own leave stars.

Volume 2, Issue 4

AUTOPSY

5" Lidu Crossette Canister Shell

Manufacturer:	*Lidu*
Shell Weight:	*1241g*
Lift Charge:	*90g 3FA black powder*
Burst Charge:	*252g KP on Rice Hulls, approx 10:1*
Shell Type:	*5" oriental canister*
Time Fuse:	*Dual chinese, 3 sec delay time*
Shell O.D.:	*4-1/2"*
Shell Height:	*5-1/2" w/lift cup, 4" without*
Wall Thickness:	*3/16"*
Cup Set:	*2" deep x 4-3/8" I.D. x 1/8" wall thickness*
Crossette Count:	*28*

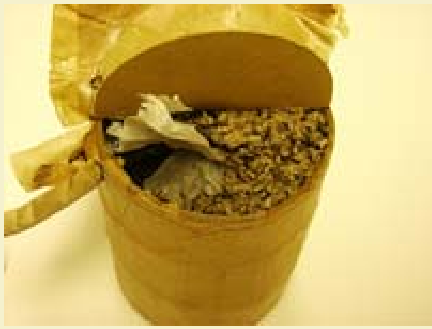

Figure 2: Thin bottom disk pealed open to reveal lift charge and filler.

Old Methods Die Hard:
It is rare that products of any sort ever take on major design changes from one model to the next. Products usually exhibit minor improvements that slowly evolve the design over many generations. This can be due to the large amount of retooling and retraining of workers required for a radical change in process, or simply from an inability to conceptualize too far beyond what currently exists. This observation clearly holds true for this first generation of oriental canister shells.

Perhaps because this manufacturer did not have access to the methods of making European style canister shells, or could not retool for such a different method, these canister shells are constructed exactly like ball shells! The only difference is that the hemispheres were pressed into a cylindrical mold instead of a spherical one.

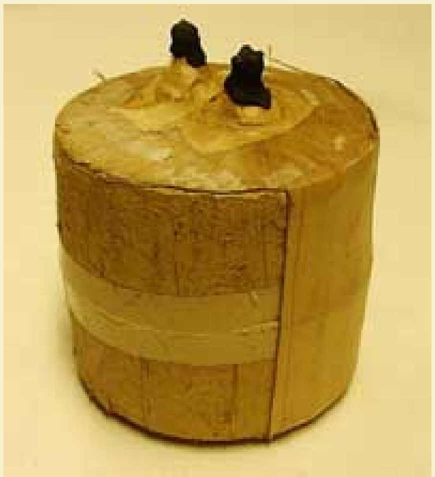

Figure 3: Stripped away paste layer shows cylindrical strawboard

Two strawboard cups of equal size are loaded as separate halves just like a ball shell would be. One "hemi" is double fused with piped time fuse just like ordinary Lidu ball shells. One side is loaded inside of a tissue paper liner so that the tissue may be folded over the loaded shell to prevent the contents from falling out when it is inverted onto the other half, as seen in Figure 4.

The inserts for this shell, which were silver crossettes, were loaded in the opposite orientation than that used for a traditional canister shell. As a result, only 28 of them could be fit inside the shell instead of the 33 that would fit by stacking them vertically. Each "hemispheres".

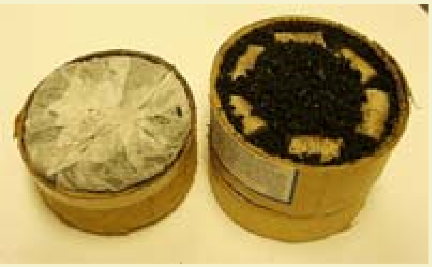

Figure 4: Shell loaded as typical for ball shells.

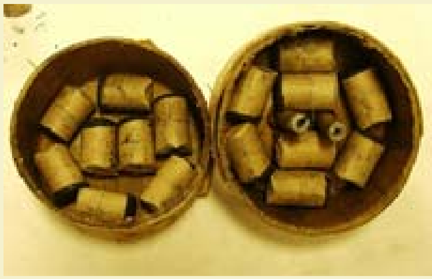

Figure 5: Placement of crossettes in second layers.

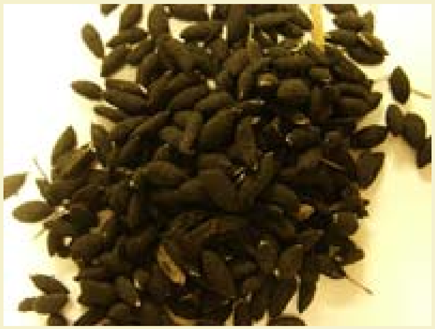

Figure 6: Closeup of KP burst charge.

half contained two rows of inserts, with the bottom row containing two central inserts that the middle rows did not have. This was probably done with the hope of achieving a round spread of crossettes in all directions.

The two halves were loaded with a burst charge of KP coated very thickly onto rice hulls. There was no central burst core, instead all empty space not consumed by the inserts was loaded with break charge the way a ball shell would be.

Continuing with the ball shell procedure, the two halves were put together and held with a band of tape, which can be seen in the cutaway in Figure 3. This assembly was then strip pasted to about 1/16" thickness. The shell was not spiked in any way, only pasted with strips of paper that ran the whole length of the shell from top center to bottom center. These strips were tapered at the top and bottom ends to prevent a conical pile-up of paper.

A string loop for supporting the leader when loading was made by running cotton twine around the shell a few times and tying it off at the bottom. The excess at the top was twisted to form the loop.

The lift cup was a rather interesting bit of over-engineering. A very strong ring of cardboard about 1-1/2" tall and 1/8" thick was attached onto the time fuse end via more strip pasting. The lift charge was loaded into a tissue liner that was glued to the bottom of the shell, then folded around the lift. The remaining empty space was filled with some type of cotton seed filler that resembled a rat's nest. The purpose of this filler is unknown and seems unnecessary. A rather thin strawboard disk was placed over the bottom and held into place with two sheets of 30lb paper pasted over the end.

It is apparent from the lift cup design that the walls of the lift cup are designed to stay attached to the shell when it is fired, helping to reduce the buildup of junk in the bottom of the mortar. Thus the walls are very thick to prevent them from blowing apart, and the bottom is very thin so that it blows out on lift.

The end result is essentially a ball shell that is in the shape of a cylinder! There was no spiking, no end disks, no pleated paper, and the concept of rolling sheets of paper around the shell instead of strips seems to be strictly avoided. The shell was also bottom fused, perhaps not realizing the increased risk of a blow-through from the higher lift pressures that occur with cylinder shaped shells.

Having seen these shells break, they definitely need improvement. As can be expected when using methods that were developed for a different shell geometry, the shell does not yield equal confinement in all directions and often results in bow tie or hose breaks. If oriental shell manufacturers continue to try their hand at canister shells, it will be interesting to watch them reinvent the wheel as their designs evolve.

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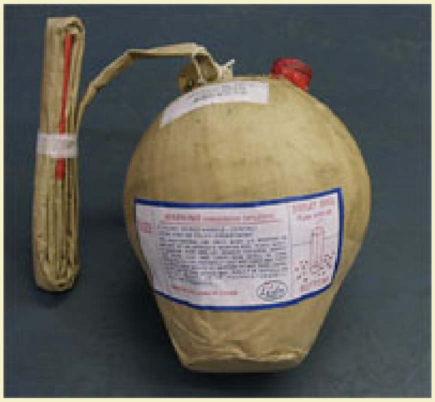
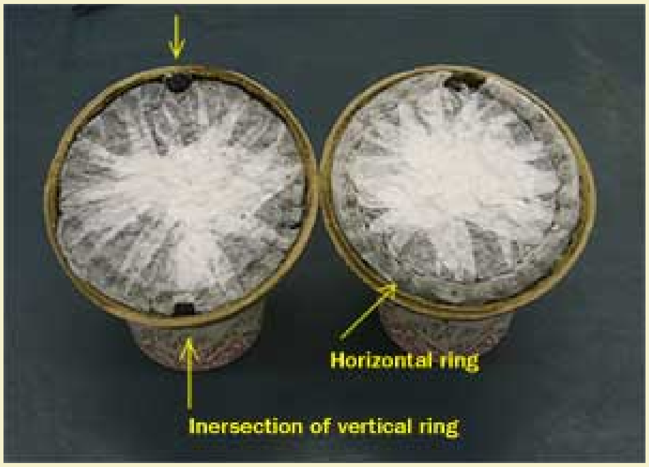
Volume 1, Issue 1

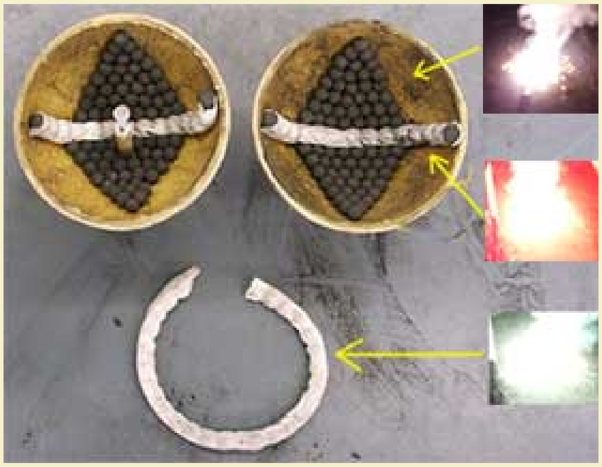
AUTOPSY

6" Silver Bow Tie w/Crossing Rings (Lidu)



Shell Weight:	*1142g*
Lift Charge:	*129g 2FA black powder*
Burst Charge:	*360g 8:1 black powder on rice hulls*
Ring Stars:	*1/2" dia. green & red*
Bow Tie Stars:	*3/8" dia. silver*
Shell O.D.:	*5-5/8" (pasted = 1/8" thick)*
Hemi O.D.:	*5-3/8" chinese strawboard hemis*
Outer Comet:	*7/8" dia. x 1/2" long, slurry primed*
Time Fuse:	*dual piped, 4 sec delay time*





Much of the shell contents seemed to have been loaded damp, as there was much clumping and sticking together of both stars and burst charge. The tissue also appeared shrink-fitted to the stars, as if lightly misted at the time of loading. The inner surface of each hemi was coated with some sort of lacquer to make them waterproof. Ring stars were rolled in one turn of gampi tissue, then lightly tacked to the hemi where the tissue seam overlapped. Key to the bow tie effect is the diamond shaped placement of the silver stars, which were also slightly stuck to one another and the hemi.

A sheet of gampi tissue was placed over the ring and pattern stars in each hemi, into which the burst charge was tightly packed. Burst was not loose and appeared to have been damp when loaded, as it was quite difficult to pry from the shell. The shell contents could not be removed even when turning the hemi

Closeup of burst charge.

upside down and shaking it! The tissue was folded over the burst and a full ring of stars rolled in one turn of gampi tissue was placed around the perimeter of one hemi.

The lift charge was not contained in a plastic bag, rather it was fastened to the shell with a sheet of gampi tissue, then pasted over with a few protective layers of kraft. The time fuse was of the piped variety, in which pipettes protrude through the hemi, which are empty during loading and pasting. After pasting and drying, about 8 pieces of chinese paper fuses are inserted into the tube, after which standard chinese time fuse is tapped into the pipe and slurry primed. These time fuses threw an aggressive burst of fire from the pipe when tested.

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Volume 2, Issue 7

AUTOPSY

6" Smiley Face Pattern Shell

Manufacturer:	*Sunsong*
Shell Weight:	*1084g*
Lift Charge:	*98g 2FA black powder*
Burst Charge:	*757g BP on Hulls, 4:1*
Pattern Stars:	*1/4" dia. round stars*
Shell Type:	*6" paper ball shell*
Time Fuse:	*Chinese time fuse, 4.5 sec delay time*

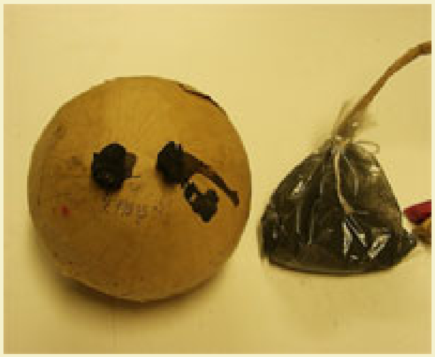

Figure 1: Double time fuse with plastic bag for lift charge.

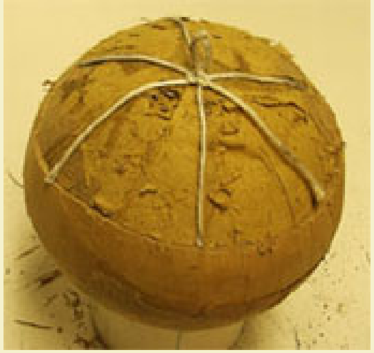

Figure 2: String wrapped around hemis before pasting.

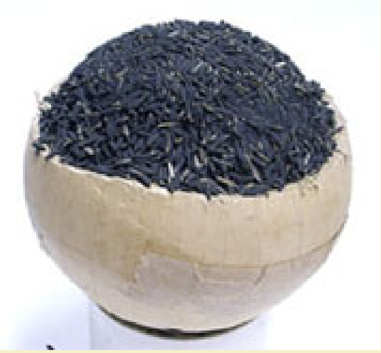

Figure 3: Densly packed rice hull burst charge.

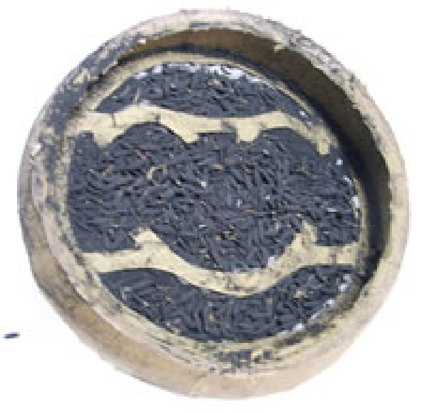

Figure 4: Cardboard template holding pattern together at center of shell.

Autopsy Report:
Pattern shells an be tricky items to dissect without disturbing the pattern. Since the pattern usually lies at the center in the same plane as the seam where the hemispheres fit together, dissecting the shell at this seam can disrupt the pattern stars if they are not securely held into position. For this reason the shell was given a lobotomy just above the hemi seam.

The quality of this particular shell seemed surprisingly low, at least in the grade of materials used. The time fuse seemed to almost look home made, and the leader contained only a single strand of black match. The shell itself was somewhat crushed, as if something heavy was placed on top of it during shipment. Even the pasted paper was an inferior quality that was easily torn off by hand- a feat which would be almost impossible with well pasted shells using virgin kraft.

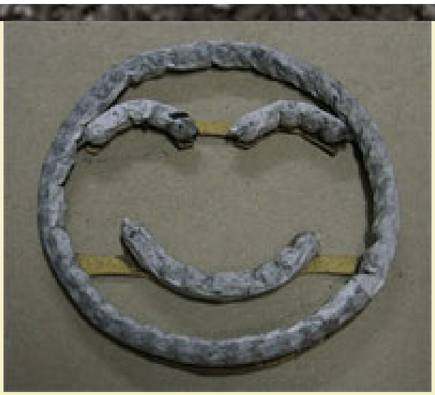

Figure 5: Pattern held solidly together by both cardboard backing and tissue wrap around stars.

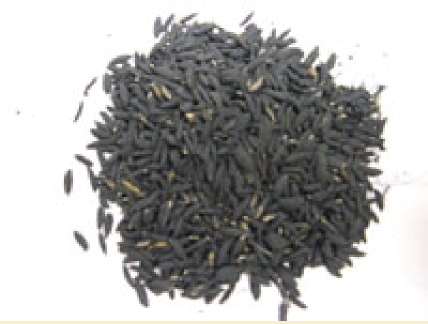

Figure 6: Typical Chinese rice hulls with BP on them.

Figure 2 reveals that six strands of twine were wrapped around the hemispheres after the shell was closed, which also attached to the loop of string used to lower the shell into the mortar.

The shell was densely loaded with typical Chinese rice hulls containing a coating of meal powder in a ratio of what appeared to be about 4:1. Figure 6 shows the appearance of Chinese rice hulls that were used to fill the entire shell.

The smiley face pattern was securely bound to a thin cardboard template that connected all the face elements together. This allows the patterns to be assembled prior to building the shell and simply inserted into one hemisphere after being filled with break charge. Figure 4 and 5 shows both sides of the pattern insert. Each row of stars was securely wrapped in a gampi type tissue paper as if they were pea pods.

To the amateur hobbyist trying to duplicate this shell I might point out that I have tried attaching individual stars to similar cardboard templates using hot glue with no success. Hot glue tends to hold long enough for the cardboard to tare and be thrown from the shell before the stars free themselves from the cardboard pieces. This results in odd clusters of stars that ruin the desired pattern.

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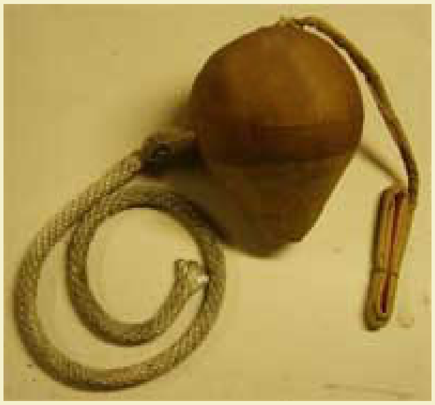
Volume 2, Issue 2

AUTOPSY

6" White Elephant Pattern Shell



Manufacturer:	*U.S. Domestic.*
Shell Weight:	*1556g*
Lift Charge:	*79g 2FA black powder*
Burst Charge:	*169g 4FA + 615g 2-3FA*
Inert Filler:	*465g meal coated 1/4" beans*
Pattern Stars:	*45 1/4" dia. white round stars*
Shell Type:	*6" plastic*
Rope:	*5/8" dia, 32" long*
Time Fuse:	*Chinese time fuse, 5 sec delay time*

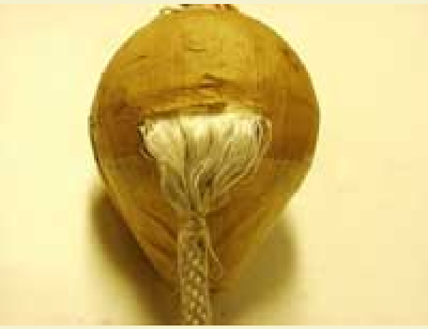


Figure 1: Rope attached at equator to stabilize pattern orientation.

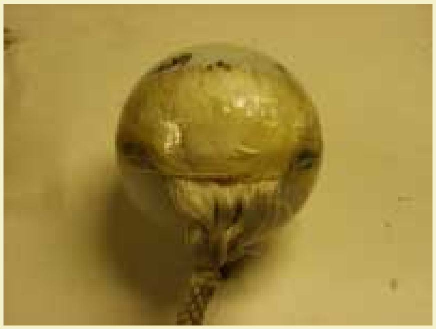


Figure 2: Fiber tape holds frayed rope end to shell casing.

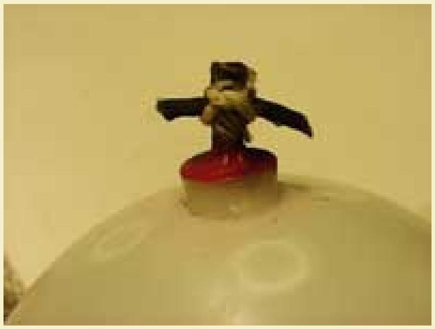


Figure 3: Center punched cross match tied with cotton twine.

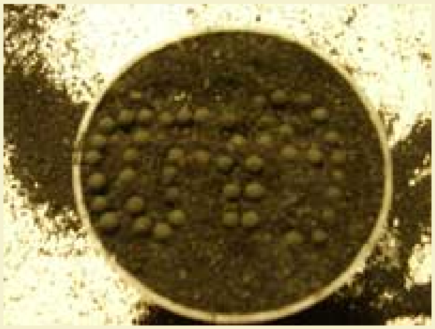


Figure 4: The elephant pattern embedded in 4FA BP within the time-fuse hemi.

Operational Theory:
An inherent problem with all pattern shells involves the random orientation of the break with respect to the viewing audience. With the shell rotating rapidly on all three axis, the chance of the shell breaking so that the viewer has the optimum perspective to see the pattern is pure luck.

One common solution to this problem is to shoot many pattern shells in a volley, thus increasing the odds that one of them will be seen in the proper orientation. Once seen, it then becomes easier to recognize the rotated patterns in the other shells.

A less frequently used method to help increase the odds of seeing the pattern in its correct orientation is the use of a rope fastened to the shell. This acts as a stabilizer similar to the way a rocket stick keeps rockets from rotating. The rope will keep the shell from rotating in two out of the three spin axis, thus greatly increasing the odds of seeing the pattern correctly. The dreaded edge view is still possible, but much less frequent.

Perhaps the most difficult aspect of building pattern shells is the need to secure the stars used in the pattern from shifting during assembly and transport. A small deviation inside the shell becomes greatly magnified when burst into the air, and shifted stars in both the horizontal and vertical plane are easily noticed by the viewing audience.

Upon examination of this pattern shell, one can see several innovations. The basic construction involves a diluted burst filler of beans, lightly coated with meal, and a mixture of black powder ranging in grain size from 2FA to 3FA. Since most of a pattern shell is empty space with a very minimal amount of stars, it is necessary to use a weak break charge and dilute it with inert material to prevent over breaking the shell.

The time fuse hemi is filled almost to the top with the diluted break charge, then a bedding of 4FA is filled the rest of the way. To keep the 4FA from migrating down into the break charge beneath it, the BP filler must be thoroughly jostled so that it completely fills in the spaces between the beans. If the 4FA shifts down into the hemi during transport, the pattern will become distorted perpendicular to the viewing plane.

The desired pattern is then placed into this bedding using 1/4" round stars. While the stars move freely in loose 4F powder, compacting the powder will essentially lock the pattern in place. It is estimated that, upon placing the pattern, more 4F powder is filled over top of it such that it heaps above the rim of the shell.

Since grain powder and the beans are not compressible, a solution had to be found for allowing the over-filled hemi to be compressed when closed, thus keeping pressure on the 4FA pattern bedding so the stars will stay put. The clever solution arrived at was the use of styrofoam packing peanuts placed at the bottom of the second hemi prior to loading the break charge into it. The styrofoam allows the otherwise non-compressible break charge in the second hemi to compress when it is closed over the over filled pattern hemi.

Hats off to this American manufacturer for their ingenuity with pattern shells!

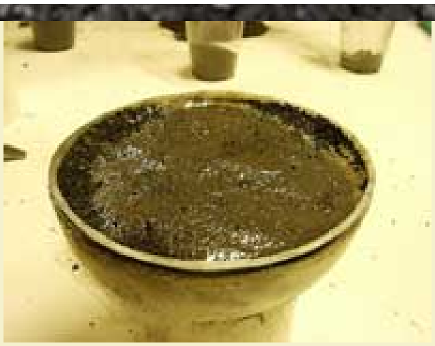


Figure 5: The other hemi is covered with thin, vented plastic prior to closing.

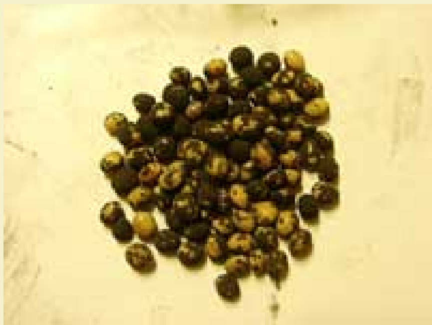


Figure 6: A mixture of inert, meal coated beans are mixed with 2FA and 3FA for the burst.

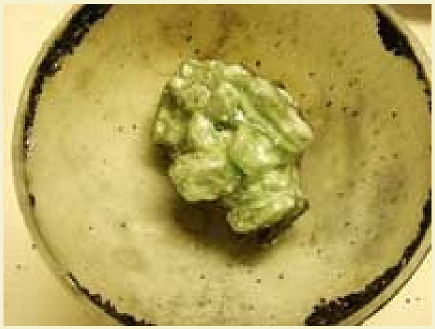


Figure 7: Styrofoam packing peanuts, wrapped in saran wrap, are grouped at the bottom of the non-fused hemi.

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Volume 6, Issue 1

AUTOPSY

7" Red Lantern Shell

Manufacturer:	*Horse Brand*
Shell Weight:	*852 grams*
Lift Charge:	*162 grams 4FA*
Burst 1:	*25 grams KP on rice hulls*
Burst 2:	*8 grams 4FA*
Hemi O.D.:	*6-3/8"*
Hemi Thickness.:	*1/8"*
Case Thickness:	*1/16"*
Time Fuse:	*Dual Chinese time fuse, 6 second*

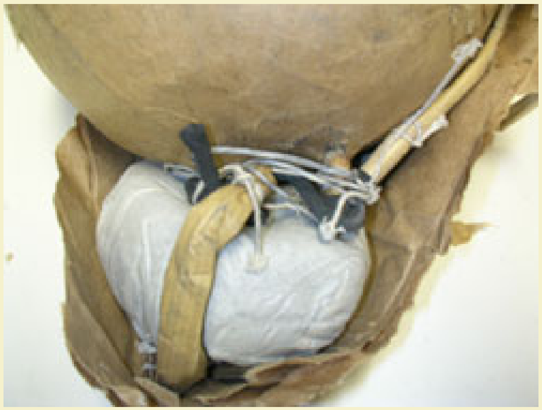


Figure 2: Leader tied to time fuse, with separate leader going into lift bag.

People have been asking me for a lantern shell autopsy for quite some time, and this month I finally got my hands on one of these shells. This is an effect you don't really see that often, probably due to the fire hazard that results when the lantern fails to open. The effect looks like a big ball of light that lingers in the air, and looks really neat when many are fired at once. They can be made in any color you want, with red and white being the most popular.

While the shell label reads "Red Lantern," the "lantern" is really just a parachute rather than something resembling a genuine Chinese lantern. When viewed from the ground, however, you really can't tell the difference. A red flare is suspended up inside the chute in order to illuminate it, and the parachute is colored red as well.

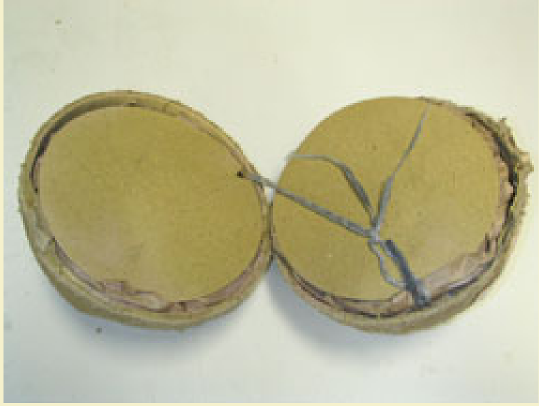


Figure 3: Shell halves with fuse running

Although this is an autopsy report, I have supplied enough pictures, diagrams and measurements to give you a good chance of reproducing something like this on your own. The most difficult problem to get around would be finding the proper material for making the parachute. Plastic can not be used due to the risk of melting, and most common grades of tissue paper are not strong enough to work without tearing. The parachute found in this shell is made from a thicker quality of gampi tissue paper and is quite strong while still being thin enough to fold up into a compact package. About the only substitute that would work equally well is thin cloth like a linen sheet. But I don't want to get any angry phone calls from your wife complaining about a five foot diameter between them.

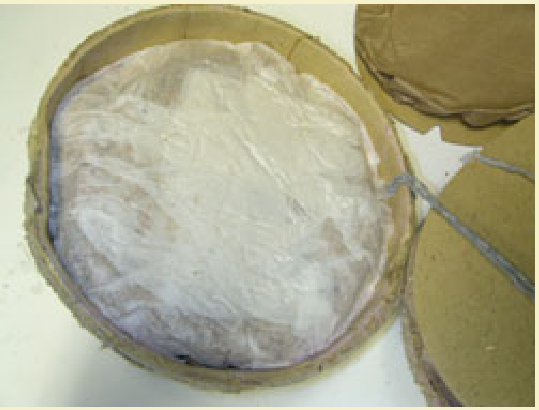


Figure 4: Tight packing of sawdust lined with tissue in the burst half.

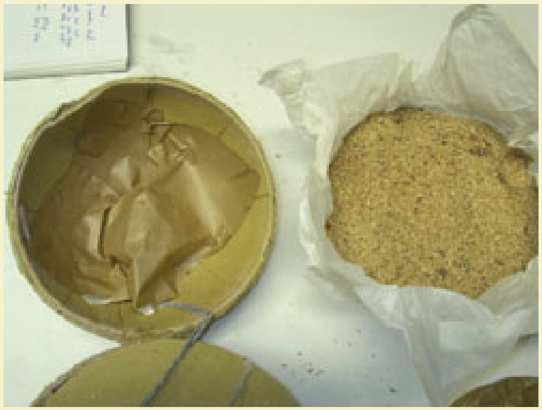


Figure 5: Small burst charge covered with 40lb kraft and tissue.

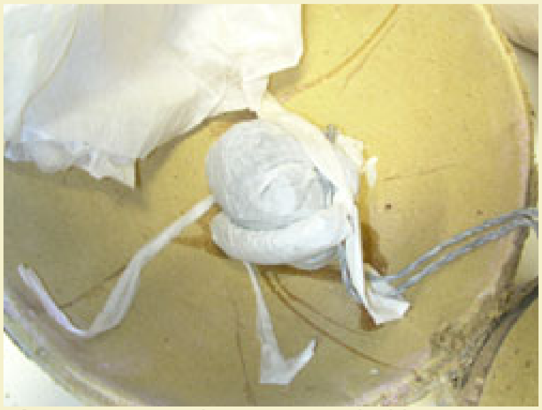


Figure 6: Burst bag surrounded by paper sleeves filled with BP.

hole in your bed linens, so control the urge OK?

The shell examined here is a 7" ball shell, which is an unusual size. The parachute could probably be scaled down slightly and fit into a 6" shell to make firing it easier, or scaled up and packed into an 8" shell for that matter. I doubt the lift or burst charges would need to be altered in either case.

Construction:

This shell is pretty unconventional from anything I've seen, although this is the first Horse Brand shell I've dismantled so maybe they are all built this way. The outer lift covering is not made from pasted paper, rather it is just a few dry turns of recycled kraft glued onto the shell. The leader is not glued to the shell at all, instead it is tied off to the time fuse to prevent it from pulling out. A separate segment of piped match is tied off on the other time fuse, which runs into the lift bag as seen in Figure 2. The lift bag is a plastic bag filled with 4FA that is then bagged again with a gampi tissue paper bag. Why this outer paper bag is used I have no idea. The time fuses are slurry primed on the ends, and a length of paper Chinese fuse is wrapped around them. The whole lift assembly seems more convoluted than necessary, but to each his own.

The amount of lift used for this shell, 162 grams of 4FA, is about three times more than the ounce per pound of shell weight rule would predict. This is one of those special cases where the ounce per pound rule does not work for calculating the lift charge, as this 852 gram shell is exceptionally light for its size. However, even if the shell was filled with stars and weighed a standard amount, the lift being used here is still a bit higher than usual. Since the 6 second time fuse also burns a bit longer than would be expected for a shell this size, we can surmise that this shell is breaking a lot higher than the standard height for a six or seven inch shell. This is no doubt to allow the parachute a good distance to fall before the chute actually opens. There is six seconds of delay before the flare even ignites, so we can assume a free-fall of somewhere around that time before the chute even opens.

The pasted casing on this shell was very minimal, resulting in a weak casing that provides little resistance to the burst charge. The pasted paper was also a cheap recycled variety compared with the typical virgin kraft most Chinese shells use. The goal is to pop the shell open with as little force as possible so that no damage is done to the parachute.

The location of all internal components is seen in the diagram below. The burst charge is located at the opposite end as the parachute, with lots of fire barriers between them.

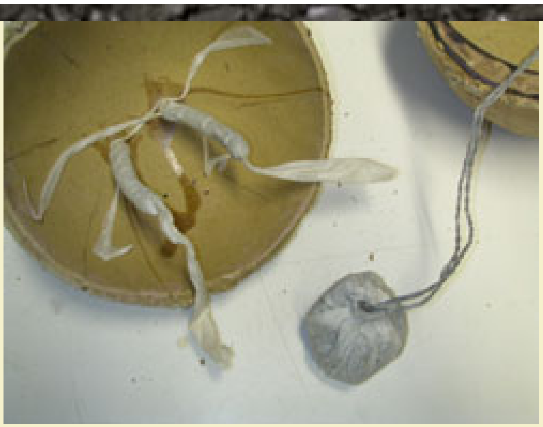


Figure 7: The BP filled sleeves connected to the time fuses.

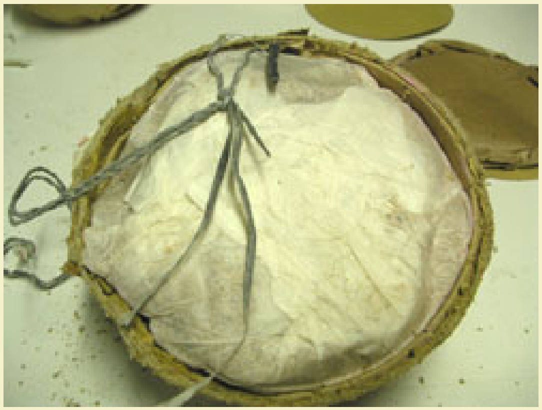


Figure 8: The parachute half (note stub of black match protruding at top).

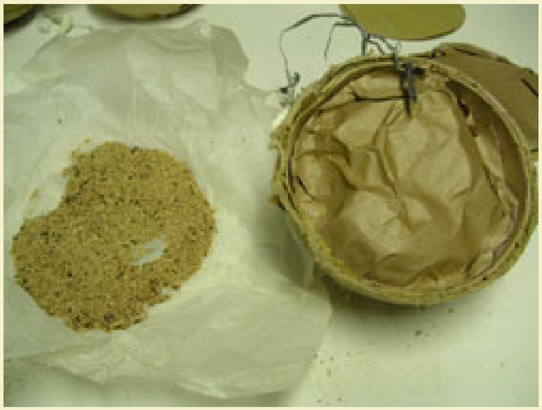
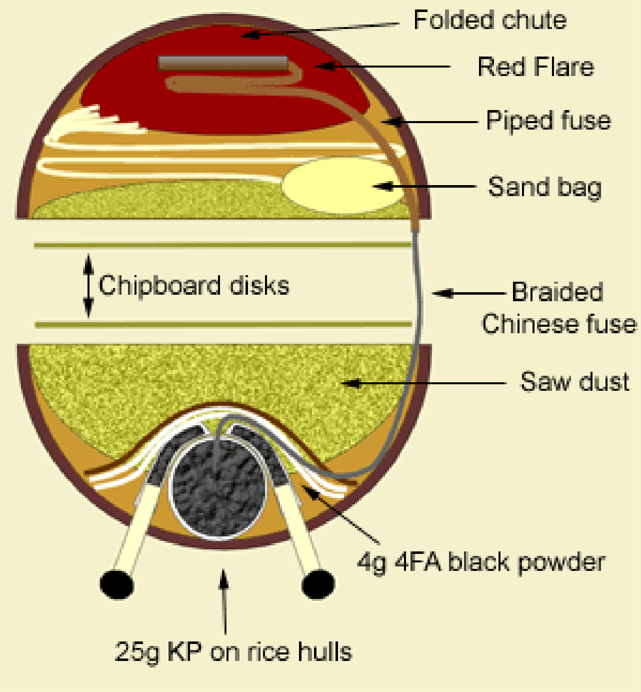


Figure 9: Small amount of sawdust lined with tissue paper.



Examining the burst side first, we find a chipboard disk placed over a thick clump of sawdust that has been packed into a tissue paper liner. The bag of sawdust is easily removed to reveal a tiny burst charge sitting in the bottom of the shell, as seen in Figure 5. The burst bag is covered with a scrap of 40 lb kraft paper, followed by two sheets of gampi tissue paper. Figure 6 shows the burst bag sandwiched between two powder filled tubes of tissue paper. The tissue sleeves are glued to the ends of the time fuse and are packed with 4FA black powder. The ends of the sleeves are left empty so that they can be tied in a knot above the burst bag to secure it in place. Note that gampi tissue is strong enough to allow knotting like this, whereas typical wrapping tissue would be torn if this were attempted.

The burst bag is filled with 25 grams of KP coated rice hulls, which are the Chinese style rice hulls that resemble the puffed rice cereal more than the domestic rice hulls sold in the states. A long strand of double braided Chinese paper firecracker type fuse runs from the burst bag into the other hemisphere, where it runs through a 26 inch long piece of quickmatch pipe that leads to the red flare embedded inside the folded up parachute.

Like everything else in this shell, the fusing going to the red flare is a strange apparatus. The braided paper fuse runs all the way through the paper tube and then ties off onto the end of the flare, as seen in the diagram below. A small strand of thick black match is located at the mouth of the piped match, but only runs about six inches into the tube.

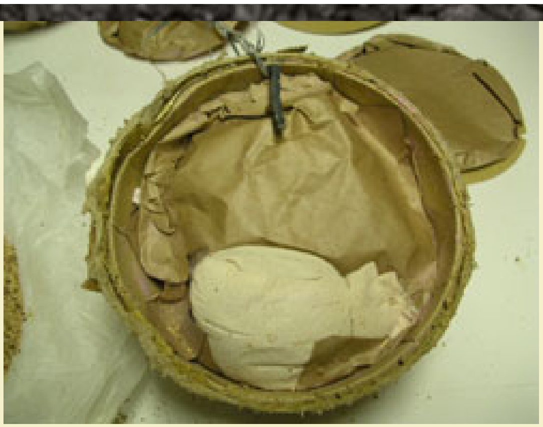


Figure 10: Cloth bag filled with sand, which is tied to parachute.

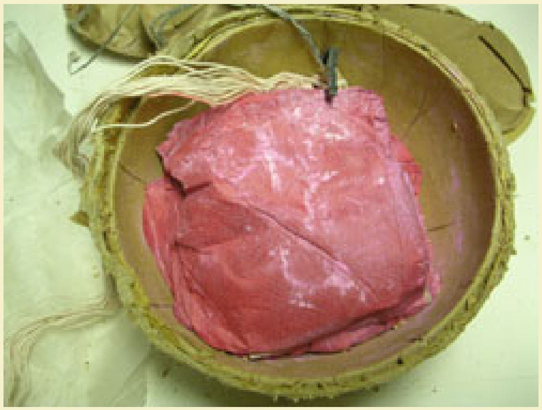


Figure 11: Paper chute is tightly packed in bottom of hemisphere.

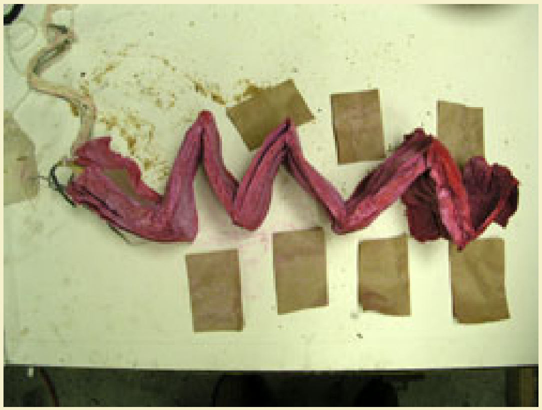
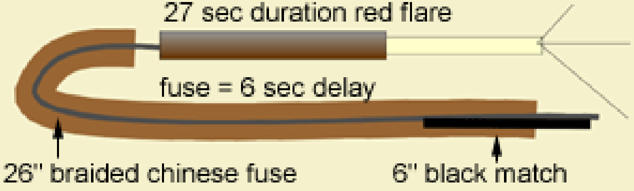


Figure 12: Accordion style folding of chute, with slips of paper placed between the folds.



The paper type fuse is only slightly accelerated when piped, unlike the dramatically accelerated burn rate of piped black match. It takes the paper fuse about six seconds to burn through the entire length of the paper tube, which creates a desired delay so that the flare doesn't ignite before the chute opens. The paper parachute is not flame resistant at all, so any timing mishaps will result in an airborne fire followed by a burning red flare on the ground somewhere.

Another advantage of the paper type fuse is that it doesn't blow the match pipe apart while burning through it. Since the paper pipe is tightly folded up into the paper parachute, the chute would be damaged if the pipe burst apart and shot flames out everywhere.

As we all know, paper firecracker fuse is notoriously unreliable. In fact, when I lit the paper fuse to do the timing tests for this autopsy, it fizzled out before reaching the pipe. Building a parachute is a lot of work to have it float to the ground unseen by anyone! A more reliable design would be to tie in a piece of time fuse at the mouth of a standard piece of quickmatch, so that it won't even take fire until after the chute is open. This also gets rid of the problem of trying to find or make a 30" long piece of paper firecracker fuse!

Parachute Construction

Next we'll look at the construction of the parachute. As previously mentioned, the parachute is made from a rather thick grade of gampi tissue. Several sheets are glued together at the edges, then a large 64" diameter circle is cut from the sheet. This circle is then reinforced with thin string glued into the paper in the pattern shown below. A continuous rim of twine is hemmed into the edge of the chute, then an inner circle of string is added at the crown by sandwiching the string between the chute and a 1/2" wide "tape" of gampi tissue that is glued down over top of it. Then eight load bearing strings are run from the edge of the chute to the center ring, as seen in the patter below. These tapped strings reinforce the chute so that it doesn't tear during the stressful jolt upon opening.

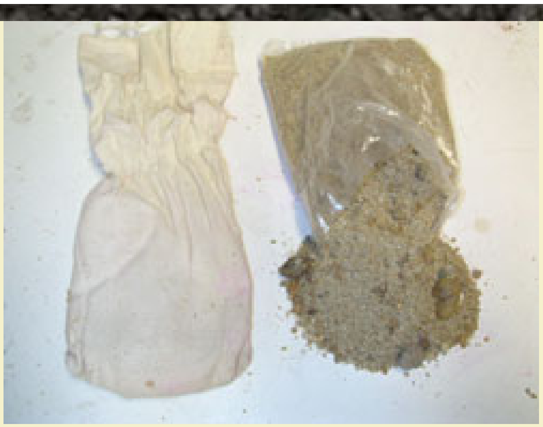
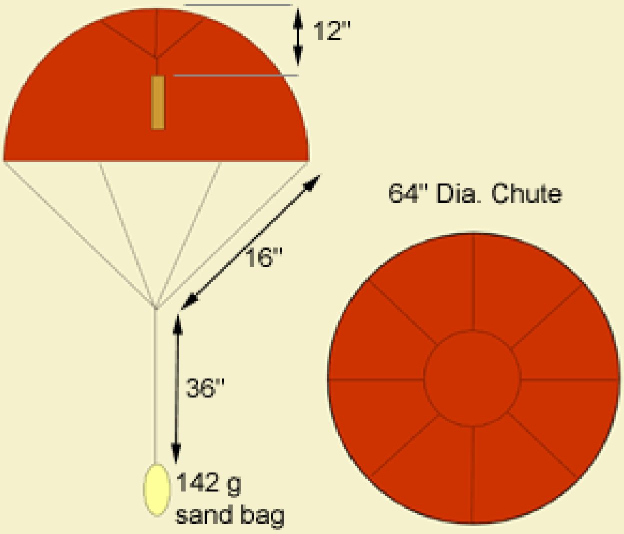


Figure 13: Cloth bag contains a plastic bag with 142 grams of sand and gravel.



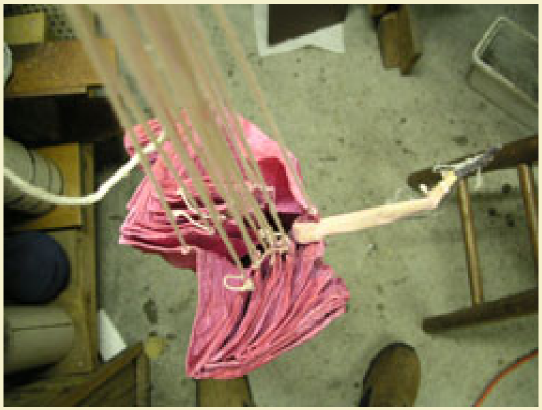


Figure 14: Piped Chinese fuse leading inside the chute where the flare is located.

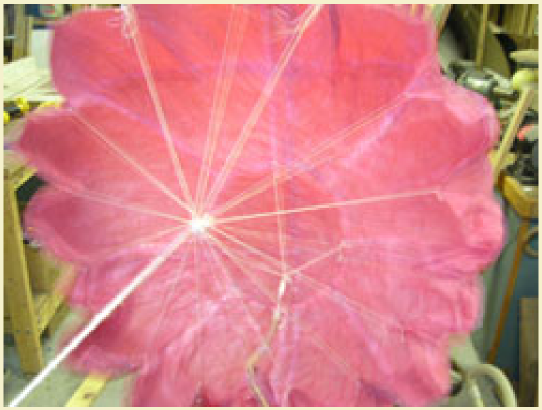


Figure 15: Four strings suspend the flare inside of the chute.

Sixteen strings are tied around the perimeter and tied together at a single point. A small bag of sand is then suspended on a long string from this point, which serves to pull the chute down with enough force for it to open during free-fall.

A 3/8" diameter flare that burns for about 27 seconds is then suspended inside the chute by four strings that attach to the crown loop. The flare hangs down about a foot from the top of the chute, which keeps it inside the canopy rather than hanging down below.

The entire chute is dusted with what appears to be talcum powder, which is done to help prevent the tightly compacted folds of paper from sticking together when it is time for the chute to open.

Loading the Chute

We will analyze the autopsy in reverse here to get a clearer picture of how the parachute was loaded. First the chute is probably hung from the crown so that the strings and sandbag hang down towards the ground. The paper is then folded similar to an umbrella, organizing the folds as seen in Figure 14. Once the chute is worked into a tight bundle, it is then folded up like an accordion as seen in Figure 12. Small scraps of kraft paper are placed between each fold, presumably as an additional aid to prevent the paper from clumping together.

The tight wadding of paper is then loaded into the hemisphere as seen in Figure 11, with the strings and piped match coming out the top. Note that this chute was really packed in quite tightly, such that it just stayed in a compressed block when removed from the shell. It is surprising that this thing even opens when dropping through the sky, as it took a bit of effort to pry the clumped paper apart. Perhaps there were problems with these chutes not opening and that's why this poor shell is here on my table, all chopped up, instead of being fired by the original owner!

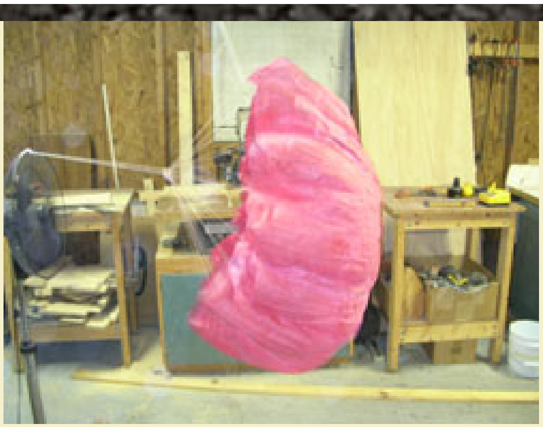


Figure 16: Side view of opened chute.

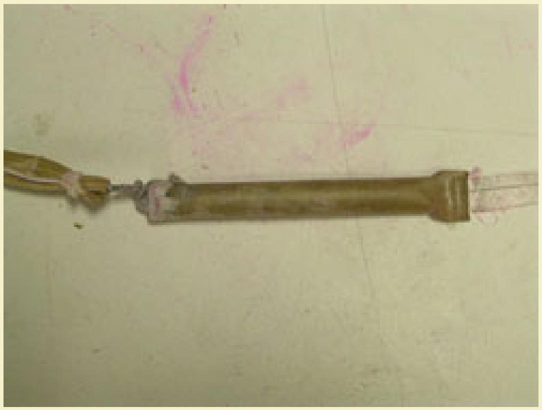


Figure 17: Close-up of the red flare, which burns for 27 seconds following a 6 second pre-ignition delay.

Several disks of 40 lb kraft paper are used to finish packing the shell. The first disk is placed over the chute, then the strings are run across the disk. Another disk is placed over the string, then the string is run back across again. A third disk is placed over the string, then the sandbag is put in place. These disks presumably play some role in preventing entanglements with the strings when the contents pop out.

Finally another gampi tissue liner is placed in the remaining space and filled with sawdust. There isn't much empty space left in this half of the shell, so not much sawdust is used. The tissue is closed over the sawdust and then a final chipboard disk is placed on top.

There you have it, the elusive Red Lantern shell revealed!

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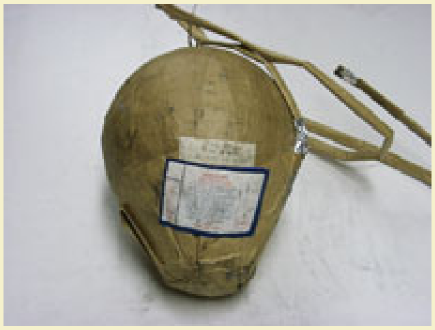
Volume 2, Issue 11

AUTOPSY

8" Gold Peony Ball Shell

Manufacturer:	*Sunny*
Shell Weight:	*2974g*
Lift Charge:	*219g 3FA black powder*
Burst Charge:	*938g BP on cotton seed*
Stars:	*5/8" to 3/4" dia. round stars*
Shell Type:	*8" ball shell, single petal peony*
Hemi I.D.:	*6-3/4"*
Hemi O.D.:	*7-3/8"*
Case Thickness:	*3/16"*
Time Fuse:	*Dual chinese time fuse, 6 sec delay time*



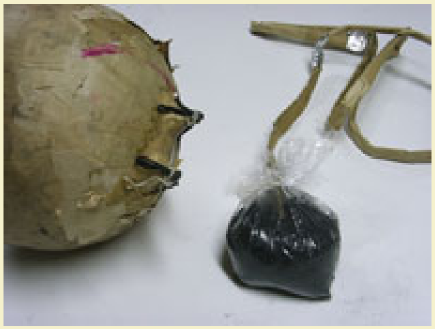


Figure 1: The platic bag of lift with time fuse tied in was pasted onto the shell.

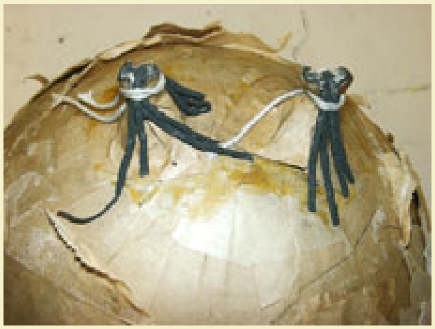


Figure 2: Time fuse crossmatched with split & tie method.

Autopsy Report:
One of the best ways to obtain a starting point for building your own ball shells is to analyze the construction of real commercial shells. While there will be slight differences in your own paper, paste and burst charge strength, imitating a commercial shell for your first attempt will still get you very close to what you want. As you progress onto larger shells that require substantially more materials to build, keeping trial and error to a minimum is very desirable. It is for this reason that Passfire Labs provides you with these Autopsy Reports.

This month we look at a simple 8" ball shell with a single petal of gold flitter stars. The shell was lifted using the typical plastic bag filled with 3FA grain powder, which is tied onto the leader and held onto the bottom of the shell with a few layers of pasted paper. Figure 2 shows the method of cross matching that was used. The time fuse was split down the middle rather than pierced, and several strands of match were inserted and tied into place. I found the string to be rather loose and easily pulled off by hand, making the probability of passfire failure higher than it should be. I would like to think this was an isolated case of poor quality on Sunny's part.

Figure 3 shows that the shell was loaded just as one might expect: stars around the wall followed by a tissue paper liner filled with break charge. I was surprised to find considerable size inconsistency between the stars. Perhaps since these are not color changing stars, it is not worth the effort to screen the stars as accurately as what I am used to seeing.

The break charge consisted of meal coated cotton seed. The ratio of meal to cotton seed was measured at 1:2, meaning 1g of meal for every 2g of cotton seed. Because cotton seeds tend to clump together, it is more difficult to apply burst charge to them in a controlled ratio. The typical procedure involves preparing a slurry of meal and working in the dry cotton seed. Once they are saturated with slurry, they are then dusted with dry meal until the point that they no longer stick to each other. Because the burst charge volume of a single petal 8" ball is so high, you do not need a high ratio of meal to cotton seeds in order to break the shell.

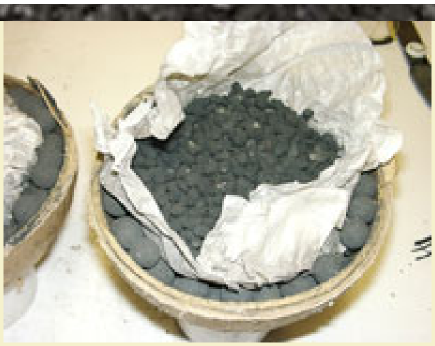


Figure 3: Black powder on cotton seed as the break charge.

The stars were meal primed and burned with a very aggressive, brilliant gold flame that shot out branching gold fragments (not to be confused with gold sparks). The composition was a dark purplish/brown color and looked as if it contained a good amount of powdered iron or steel. No visible core was found at the center of these stars. Slight imperfections in the roundness of the stars suggests that they may have been rolled from smaller pumped or cut stars as the core. This type of shortcut is easy to get away with when stars are not color changing.

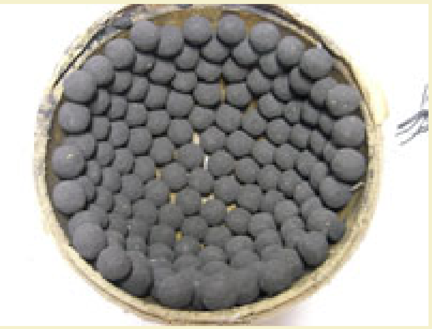


Figure 4: Single color stars ranging from 5/8" to 3/4".

The contents of this shell were repackaged into a new set of hemispheres and pasted in with 14 layers of 70 lb kraft. The lift quantity was decreased to 185 grams rather than the original 219 grams supplied with the shell. This was due to the fact that home-made lift equivalent to Goex was used in place of the weaker black powder used by the Chinese. The shell was fired and observed to achieve the original commercial quality performance at the correct altitude.

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Volume 3, Issue 1

AUTOPSY

8" Ring Shell

Manufacturer:	*Sunny*
Shell Weight:	*2208g*
Lift Charge:	*200g 3FA black powder*
Burst Charge:	*1125g BP on small cotton seed*
Stars:	*3/4" dia. round stars*
Hemi I.D.:	*7"*
Hemi O.D.:	*7-1/4"*
Case Thickness:	*3/16"*
Time Fuse:	*Dual chinese time fuse, 6 sec delay time*

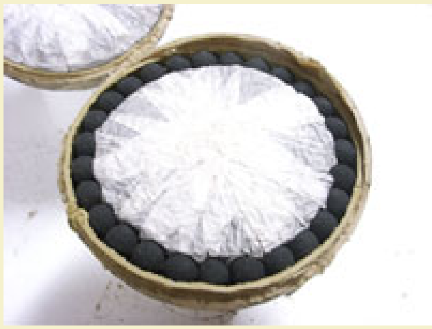

Figure 1: Ring stars, surprisigly not rolled in tissue paper.

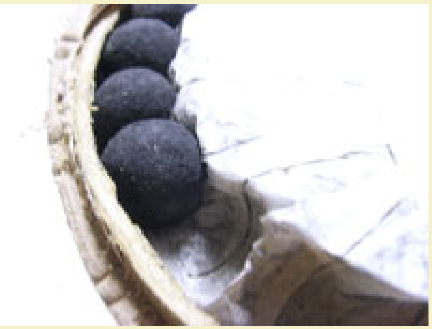

Figure 2: Stars are wedged tightly into a tissue paper trough.

Autopsy Report:
As a hobbyist, the thought of an 8" ring shell seems rather silly to me. Why spend all the materials and time pasting in a big shell to get a ring, then have some spectator say "all I saw was a line in the sky!"

But apparently these shells are cheaper on the commercial market than other large shells with single and double petal star effects. So perhaps this is one method display operators use to increase the larger caliber shell count in their shows without raising the price too much.

Given the number of ring and pattern shell construction techniques that have already been investigated on this site, I didn't really expect to find anything new here. But to my surprise, this shell packed a few tricks I have not seen before.

The first thing you notice in Figure 1 is that the ring stars were not rolled up in tissue paper, which seems the be the standard method of packaging ring stars used by the Chinese. The stars were also not attached to the case or each other in any way. The case was first lined with tissue paper which was then filled with burst charge until level with the top. The paper was then folded over into the center and the stars were wedged into place around the perimeter, as seen in Figure 2.

Like many Chinese shells I have examined, the contents seem to have been loaded in a damp state. The tissue paper had tell-tale wrinkles that indicate that it was wet when loaded. Since the Chinese use a type of tissue paper similar to coffee filter paper, it does not tare when damp. The burst charge also has the characteristic of a solid clump that was packed in a slightly damp state. It is hard to say just how damp the components are when loaded, or how they are dried afterwards, but this method seems to result in very tightly packed contents that do not even spill out of the case when inverted.

It is also interesting to see just how much tissue paper can be piled up at the center of a shell without causing a fire block. From Figure 1 it can be seen that both halves of the shell had several layers of paper overlapping at the center, yet the fire propagates through this without any problems.

The other trick used in this shell can be seen in Figure 3. Because the volume occupied by the burst charge is so large in an 8" ring shell, some of the empty space was filled with an inert filler to reduce the amount of burst charge used to break the shell. Figure 5 shows a close-up of the filler, which is some kind of soft, fluffy material that looks like ground up cotton seeds. The filler was packed into each end so that it was about 1-1/4" deep at the center, then the tissue liner was placed over this and loaded with the burst charge.

The burst charge was black powder coated onto a smaller size of cotton seed that had a large range of particle sizes. Figure 6 shows the granular nature of this material, which almost looked like rough powder.

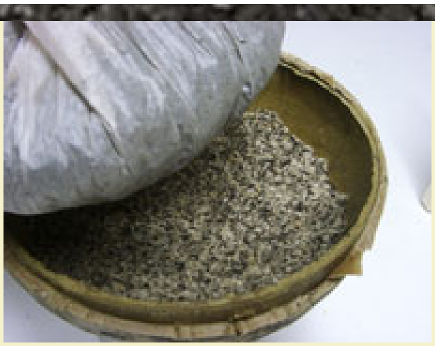
Figure 3: Inert filler used at both ends of the hemispheres to reduce the volume of burst charge.

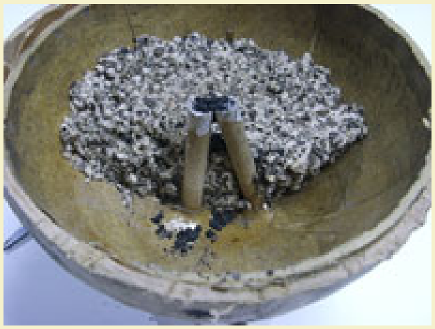
Figure 4: Thickness of filler was measured to be 1-1/4" deep at center.

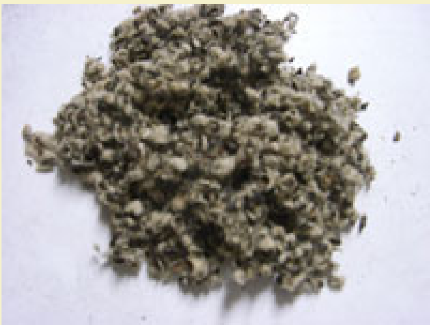
Figure 5: Closeup of filler reveals some sort of ground cotton seed material.

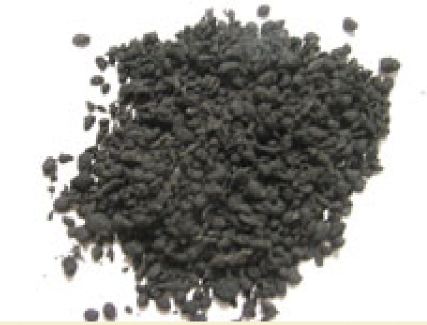
Figure 6: Burst charge was black powder on smaller variety of cotton seed.

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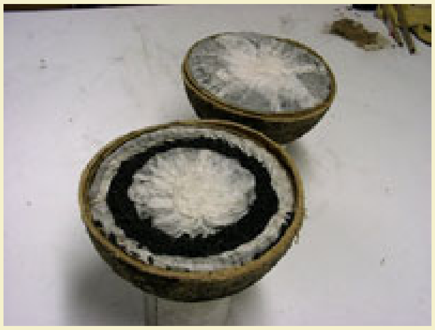
Volume 3, Issue 2

AUTOPSY

8" Saturn Shell



Manufacturer:	*Sunny*
Shell Weight:	*2737g*
Lift Charge:	*200g 3FA black powder*
Outer Burst:	*1363g BP on rice hulls*
Inner Burst:	*150g KP on cotton seed*
Ring Stars:	*5/8" dia. round stars*
Planet Stars:	*1/2" dia. round stars*
Hemi I.D.:	*6-7/8"*
Hemi O.D.:	*7-1/8"*
Case Thickness:	*3/16"*
Time Fuse:	*Dual chinese time fuse, 6 sec delay time*

Autopsy Report:
I was very interested to see the internals of this particular shell, since I have tried many times without success to produce a good Saturn shell. The concept is simple enough: A ring shell with an inner sphere of stars that produces a break looking like a planet with a ring around it. The trick, however, is getting a good spherical pattern for the planet that is also the right size in relation to the ring.

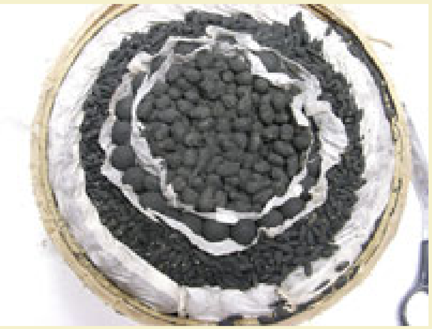


Figure 1: Half containing ring stars and inner planet stars. Note the layers of tissue used to hold the planet stars.

My own attempts generally involve loading a set of inner hemispheres with stars and then taping them together as if building a small shell. This shell is then inserted into one hemisphere of the outer shell, filled around with BP coated onto a coarse material like puffed rice cereal, then gluing in the ring stars with hot glue. The other half is filled solid with burst except for an indentation made with a hemi the same size as the inner shell. The two halves are then quickly slapped together and tamped closed.

The commercial shell shown here uses a much simpler method with no central container to hold the inner stars. A form is used to produce a cavity in the outer break charge, which is then lined with tissue and filled with a layer of 1/2" stars. It seems hard to believe that this would produce a good round inner break, since even my own encased planet stars tend to distort on the axis perpendicular to the seam between the two hemispheres.

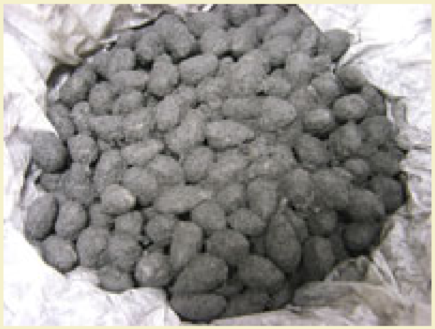


Figure 2: Burst charge of KP on cotton seed loaded into planet stars.

Perhaps part of the key is the use of a faster burning KP burst charge inside the planet stars seen in Figure 2(coated onto cotton seeds) relative to the slower burning BP break charge used in the outer layer (coated onto Chinese rice hulls). The ratio of size between the inner shell and the outer shell is also worth noting, with the inner shell being about half the diameter as the outer shell.

There is a belief that the distance a star travels from the center of the break is determined by the size of the star. I disagree with this theory and maintain that distance traveled is largely determined by the distance the star is located from the center of the shell. You can put very large comets just inside the star layer of a color break shell and observe that the comets never outrun the smaller stars in front of them. Thus, even if you use tiny stars for the planet layer, making the inner layer to big will cause the stars to follow closely behind the ring until the tiny stars burn out. The tiny star method also results in a planet that burns out too quickly. As can be seen here, a larger star is used and the inner petal is simply made smaller (4-1/2" O.D. in this case).

The ring was made in the typical Chinese method of rolling the stars in tissue paper as seen in Figure 4. Interestingly, the ring looks to have been rolled too short in this case and a spacer made from three additional stars rolled in tissue was required to fill in the resulting gap to complete the ring. I can't help but hear the phrase "no rice for you!" when looking at this repair job.

Looking at images 5 and 6, it is quite amazing just how much tissue paper can be piled up without causing a major fire block. Overlapping tissue from three separate liners pile into the center of each hemisphere, meaning that the fire entering one side of the shell must get through overlapping tissue from all six liners in order to ignite the burst charge at the center of the opposite hemisphere! Perhaps the porous nature of Chinese tissue paper makes fire transfer less of a problem, or maybe the extreme heat consumes the tissue so quickly that it's as if it wasn't even there.

It is worth noting once again that Chinese rice hulls are quite different from typical rice hulls used in America. Chinese hulls tend to be the full sized hull with the rice grain removed from inside. These hulls produce a nice football shaped grain that compresses very little when used for break charge, with lots of gap space to allow rapid fire transfer between the grains. American hulls are more like shredded flakes that produce a dense yet compressible break charge with less air gaps for flame propagation.

I have found that the compressibility of American type rice hull break charges is problematic in trying to keep the planet sphere of a Saturn shell from deforming. The use of puffed rice cereal break or even granular rough powder works much better and is a closer approximation to the characteristics of the rice hull charges used by the Chinese. While rough powder will work, it adds unnecessary weight and consumes more BP than is necessary. Puffed rice cereal is really the ideal substitute for approximating real Chinese rice hulls.

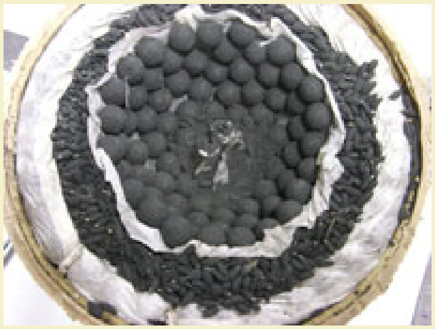


Figure 3: 1/2" dia planet stars set into 4-1/4" dia pressed cavity.

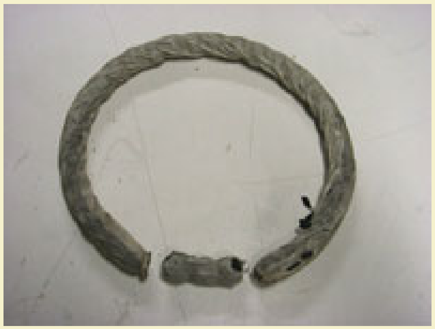


Figure 4: 5/8" ring stars rolled in tissue. Note the spacer link.

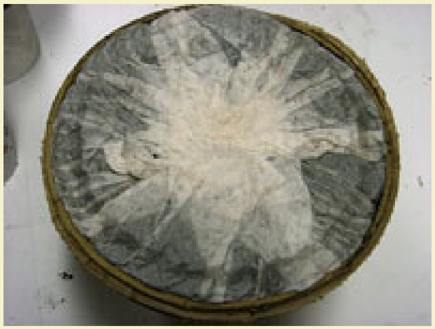


Figure 5: Other half containing only the planet stars.

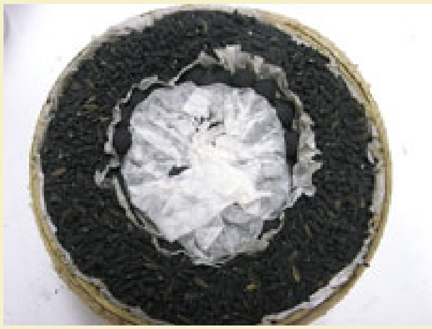


Figure 6: Digging through the 3 layers of tissue to get to the center.

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Volume 5, Issue 4

AUTOPSY

10" Double Petal Ball Shell

by **Michael Fales**

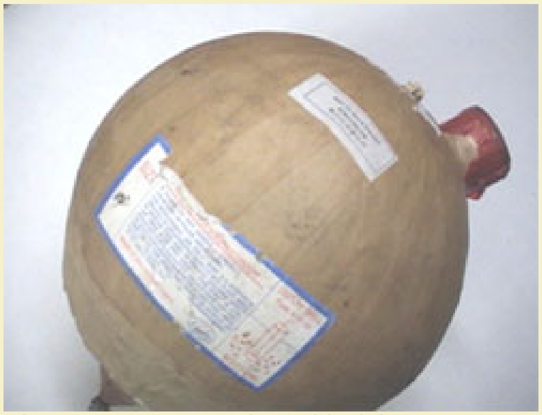

Figure 1: Outer casing with rising comet.

Manufacturer:	*Lidu*
Shell Weight:	*6342 g*
Lift Charge:	*Unknown*
Outer Burst:	*1000 g BP on cotton seed*
Inner Burst:	*256 grams BP on cork bits*
Outer Stars:	*1" red to blue peony stars*
Inner Stars:	*1/2" silver streamer stars*
Hemi I.D.:	*8-13/16"*
Hemi O.D.:	*9-3/16"*
Case Thickness:	*3/16"*
Time Fuse:	*Dual Chinese time fuse -5.8 second*

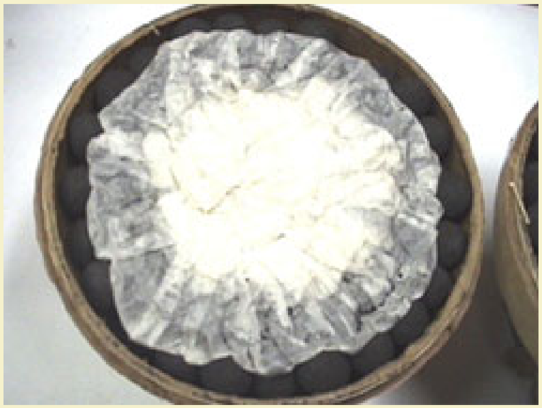

Figure 2: Hemispheres separated showing tissue liners.

Construction:

The following autopsy provided nothing out of the ordinary. The shell was laid out just as you would expect. You can see in Figure 1 that a small sheet of glassine paper is held in place with a small rubber band over the comet. This paper is to cover the exposed prime composition for safety reasons during shipping and handling, while the firestorm of blow-by gases that engulf it during lift will easily burn the paper away and ignite the comet.

There is a loop of string protruding from the top of the shell which the lowering cord is attached. These loops are usually present on all Chinese shells, but become particularly important for shells larger than six inches when lowering them into the mortar. The string is wrapped around the hemispheres before any pasting is applied, then pasted over with all the layers of paper to insure that the string does not tear out when lowering these heavy shells. While the the string loops have proven to be quite strong, the cord attached to this loop has been known to break when dropping large shells, giving quite a scare as the shell plunges to the bottom of the gun. Jute twine is particularly prone to unexpected breaking. Some higher quality manufacturers have switched to a nylon type cord for these larger shells in order to prevent this problem.

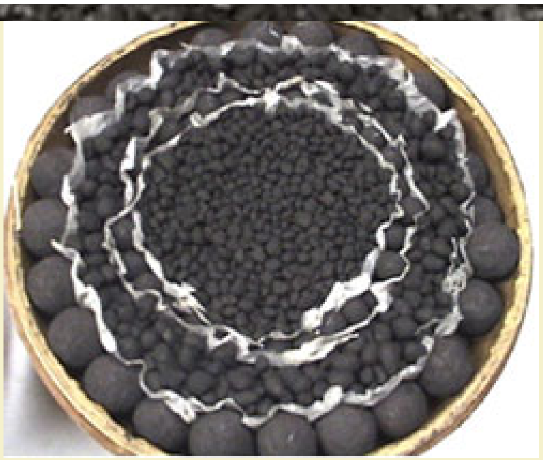

Figure 3: Tissue paper cut away to show separate petals and break charges.

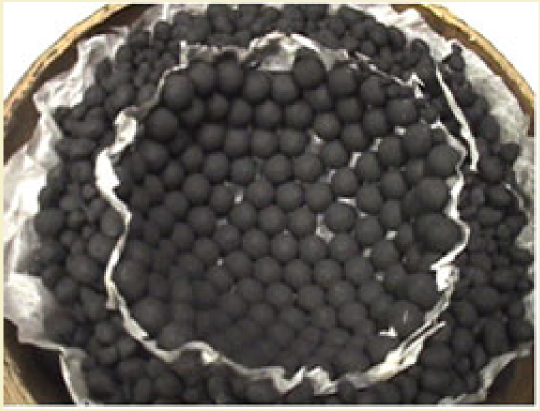

Figure 4: Inner break charge removed to reveal inner petal stars

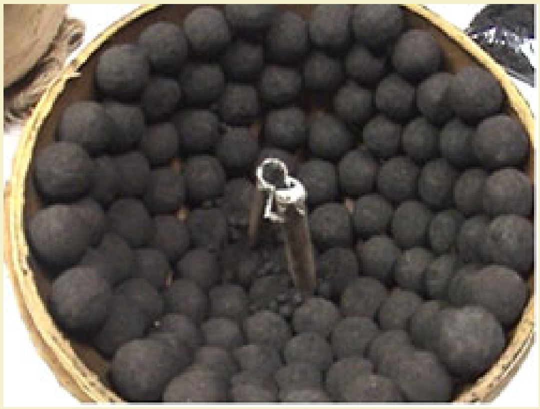

Figure 5: Outer break charge removed to reveal passfire tubes in lower hemisphere.

Cutting open the shell casing reveals a hefty 3/16" thickness of pasted paper over a set of 3/16" thick hemispheres, giving a total case thickness of 3/8". This provides solid confinement so the shell will break hard using only a simple BP break charge. The Chinese tend to use a thinner weight of "blonde" type kraft paper for pasting all their shells, and it is quite difficult to figure out exactly how many layers are applied since there are difficult to count once stuck together.

Like all previous ball shell autopsies, the internal contents seem to have been packed damp such that everything is stuck together in a clump. The dried and shrunken tissue paper seen folded down in Figure 2 provides further evidence that everything was damp at some point. The rigid clump resulting from this damp loading probably goes a long way toward providing a clean pattern with good symmetry, since the stars can not easily shift around and fall out of place during the long boat ride and bumpy handling it must endure before finally making it into a mortar.

Figure 3 shows the tissue paper cut away to reveal a total of three liners between the various layers. The shell is first loaded with 3096 grams (6.8 pounds) of 1" diameter color changing peony stars to form the outer petal, which change from red to blue. A cross section of one of these stars can be seen in Figure 6, revealing what looks like a pretty thin outer prime. Several of these stars were shot hard from a star gun and lit without failure, so the prime seems to get the job done.

Next a tissue paper liner was placed over the outer petal and filled with a burst charge of BP coated cotton seeds. The second tissue liner is formed into a 5-5/8" cavity in which the inner petal stars are placed. There is no rigid type of inner hemisphere used to hold the inner petal stars, only the thin tissue liner. The worker must use a 6" hemisphere to form a cavity with the tissue conformed to the exterior. The outer break is inserted around this hemisphere and packed tightly in place. Then the hemisphere is removed leaving the tissue paper cavity ready to be lined with the inner petal stars.

The inner petal was filled with 1/2" silver stars that burn fierce and fast, probably an aluminum/perc flitter mixture. Another tissue liner is placed over these stars and the remaining space is filled with an alternate burst charge that is made from bits of cork coated with BP. The cork bits are smaller than the cotton seeds, approximately the size of 2FA after being coated. There seems to be an advantage to having a slightly stronger burst charge in the center petal of double petal shells, as this is the second time this has been found during autopsies. During the 8" Saturn shell autopsy, we found that the inner petal had an even stronger burst charge that switched over to KP coated hulls. In the shell seen here, the smaller core size would only produce a marginally stronger burst charge since they are still coated

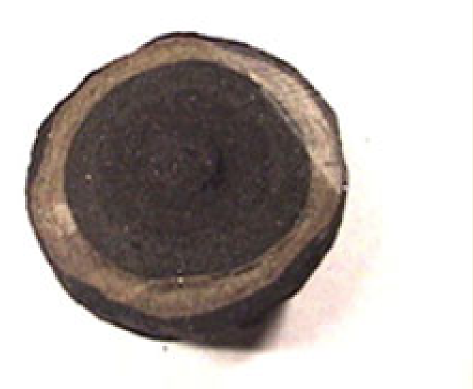

Figure 6: Cross section of 1" outer petal star reveals layers of color changing composition.

with BP.

All three layers of tissue are gathered to the center and pushed down flat. It is not known weather the shell is first dried out before assembling the halves or just assembled and force dried in a heated oven, with the moisture escaping through the empty passfire tubes. I suspect it is this second method, as the shell would not be able to settle when being closed if the contents were all dried and locked into place.

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Volume 5, Issue 1

AUTOPSY

19 Shot Chinese Cake

by **"Big G"**

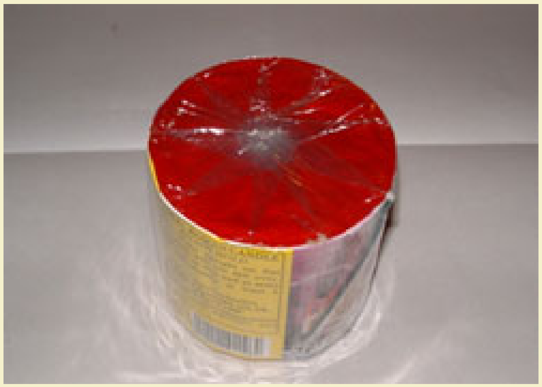

Figure 1: A generic 19 shot round cake.

Manufacturer:	*Chinese, Unknown*
Type:	*19 shot repeater cake*
Mortar I.D.:	*1/2" (12 mm)*
Isert I.D.:	*5/16" (8 mm)*
Insert O.D.:	*7/16" (11 mm)*
Insert Wt.:	*6 g*
Lift Charge:	*1 g 2Fg*
Effect:	*alternating whistles & color comets*

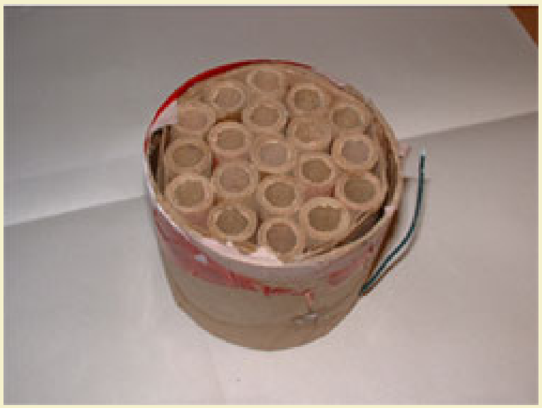

Figure 2: Bundle of 19 tubes inside a large outer tube.

Construction:
The cake dissected in this article was bought in a small fireworks outlet in Nevada, while the cake showin in Figure 1 (which looked better from the outside) was bought in East UK. The appearance and performance of each was so similar they might have been manufactured by the same factory.

Striping the outer wrapper in Figure 2 reveals a large spiral tube used as a container for nineteen 1/2" I.D. (12mm) convolute tubes. The spiral tube is somewhat larger then the bundle of 19 tubes, so a few turns of cardboard was wrapped around the bundle so that it would fit tight into the outer tube. All the tubes are held in place by a bit of glue.

In Figure 3 we can see that all of the tubes are mounted on a single long piece of 2mm fast burning Visco type fuse. The tubes are threaded onto the visco one at a time, then rolled up into a bundle. This is a much faster method of fusing cakes than inserting small fuse links between each pair of tubes. Rolling the tubes into a round cake insures that the opening of one tube does not face the opening of the next tube, thus avoiding the chain-reaction problem that can occur when the lift gas from one shot fires through the hole of the next shot.

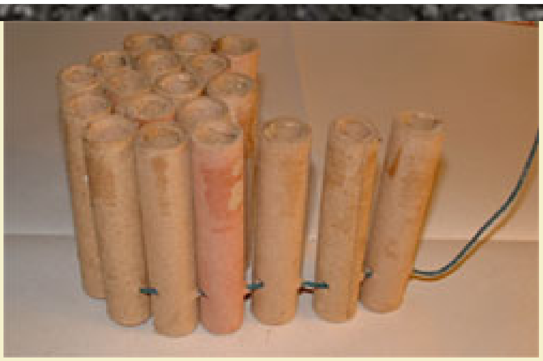

Figure 3: Shot tubes threaded onto long strand of Visco.

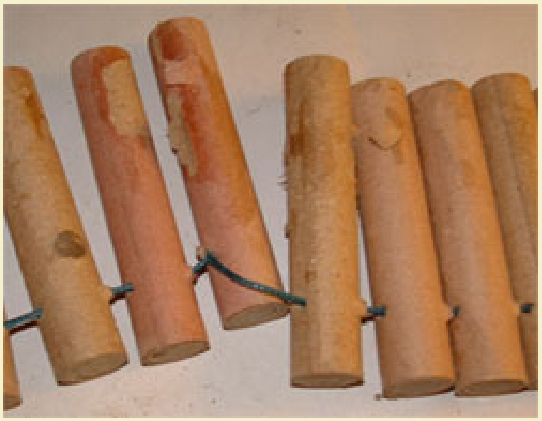

Figure 4: Two smaller chains used to make complete chain.

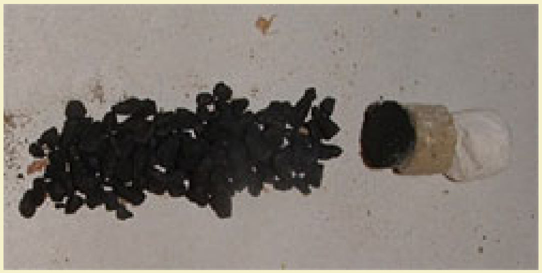

Figure 5: Insert components.

This cake used two pieces of Visco to build the complete chain, where the end of one Visco was pushed into the same hole as the start of the second Visco as seen in Figure 4. This was probably done to save time, since the longer the tube chain is, the longer it takes to thread each tube into place. Stringing two smaller chains is thus faster than stringing one long chain.

Each shot fires a 5/16" I.D. (8 mm) convolute tube which is held in place with a plug glued into the mortar above it. The insert is filled half way with 1g of 2Fg lifting charge, rather than placing the lift in the bottom of the shot tube. This technique has advantages, such as avoiding the tedious task of keeping track of which tubes have been "lifted" when loading a round style cake. Each insert is a self contained unit that is simply dropped into each shot tube.

A central clay plug separates the lift charge from the rising effect. Above the clay plug, the inserts are charged with either whistle or colored star composition, then primed with BP. Upon ignition, lift gases are confined long enough to ignite the prime on the top side of the insert before firing it a good 30 feet into the air.

Such simple cakes aren't that impressive by themselves, but they can be effective in large numbers or when used in conjunction with other effects. Letting them fire while shooting rockets in your backyard garden display is a good way to avoid dead sky!

Editor's Note: using the fast burning Visco type fuse is essential when using the "threaded" method of fusing cakes. Standard visco results in too much delay between shots, and raw black match will side-ignite and cause the whole cake to fire in rapid succession.

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Volume 5, Issue 5

AUTOPSY

45mm Italian Candle

by **Michael Fales**

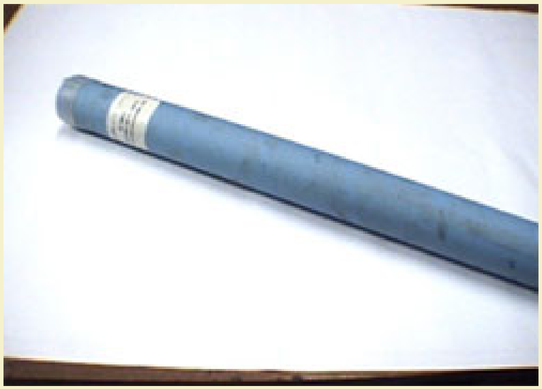

Figure 1: 45 mm crossette display candle from Italy.

Manufacturer:	*Panzera, Italy*
Total Weight:	*1330 g*
Lift Charge:	*8.5 grams 3FA (per shot)*
Star Size:	*1-9/16" dia. crossettes*
Delay Method:	*7/8" thick wadding w/timer spool*
Delay Period:	*3.5 seconds*
Tube I.D.:	*1-3/4"*
Tube O.D.:	*2-3/16"*
Tube Length:	*31-5/8"*
Tube Wall:	*7/32" thick*

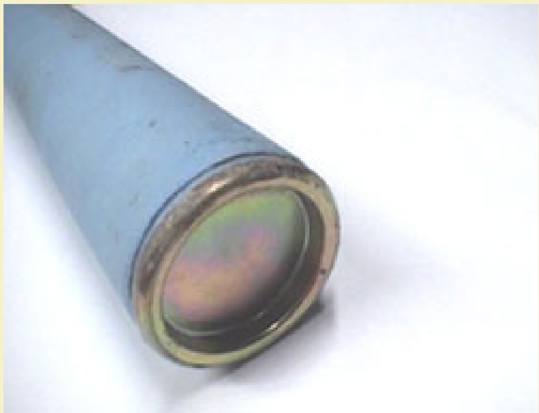

Figure 2: Spiral tube plugged with metal end cap at bottom.

Construction:
This autopsy reveals the inside workings of a large caliber Italian display candle. The candle tube is spiral wound and covered with a wrap of thin blue paper both on the outside and inside of the candle. The inner layer of paper is used to cover the spiral groove in the tube wall that is inherent with spiral wound tubes. The spiral grooves can cause potential problems with fire skipping past the delay bulkheads and prematurely firing shots out of sequence, thus ruining the entire effect. The blue wrap on the inside fixes this problem by smoothing out the tube and eliminating the groove. This allows the use of more readily available and cheaper spiral wound tubes in lieu of the more expensive convolute wound type. The bottom of the tube is closed using a crimped metal end similar to what is used for mailing tubes.

The label gives the manufacturer name and factory location, along with the item number and a description of the candle in both Italian and English. The Italian effect name given on the label is "Crocetta," which refers to the crossette effect (and here I thought "crossette" was the Italian name!). The English description reads "Comets & Rays," with "rays" apparently referring to the splitting portion of the crossette effect.

The candle construction is revealed in Figure 3 with half of the cardboard tube removed. A plastic flanged cap with a hole in the center is pushed down into the tube along with a small piece of blackmatch. This cap resides 11-1/4" down inside the tube. To display the candle the user must provide fire down into the tube to light the small piece of blackmatch or the prime on the comet. The common way is to bare the end of a long piece of quickmatch and place it into the candle. The quickmatch is then folded over the top of the candle. The plastic cap is then placed back on top of the candle holding the quickmatch in the small notch provided.

The first crossette in the tube is placed prime side up so that it can take fire from the top. The flash of fire from the prime will travel down around the comet and ignite the lift charge, thus blasting the comet and plug out of the candle. The timing elements between shots consist of a 7/8" thick felt plug with a plastic spool at the center. The center of the spool is filled with a dried black powder type slurry to provide the fire to the next shot. When lit a fierce flame approximately 6 inches long shoots from the top of the spool. After a 3.5 second burn time, a small burst of fire shoots out from the other end to ignite the next shot. A cardboard disk with a hole punched in the center sits atop the felt plug. The hole provides spacing so that the comet is not directly sitting on top of the plastic delay spool. This will keep it from getting damaged as well as providing better fire transfer during lift. Both the felt plug and cardboard disk are 1-13/16" in diameter, just 1/16" larger than the ID of the candle tube. This creates a snug fit when shoved into the tube over the previous crossette comet. The felt bulkheads create an effective firewall between each shot, yet is light and easily ejected with the next lift charge.

The lift charge consists of 3FA black powder with a very shiny coating of graphite. It is so shiny and silver in fact that it looks to be small granules of metal. The lift charge weight was evenly spread among the shots at 8.5 grams each.

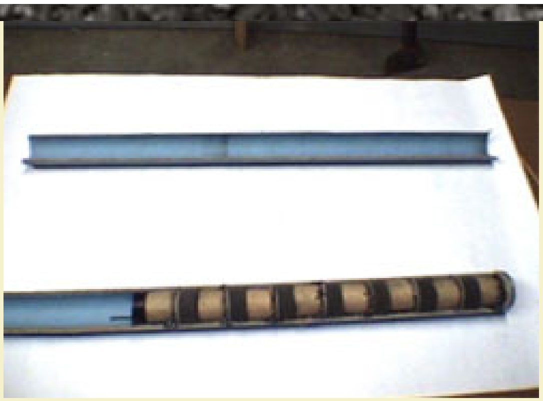
Figure 3: Cross section showing arrangement of eight shots.

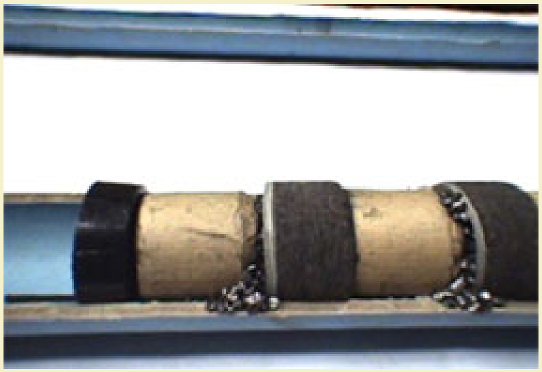
Figure 4: Closeup of crossette, lift and delay wadding for each shot.

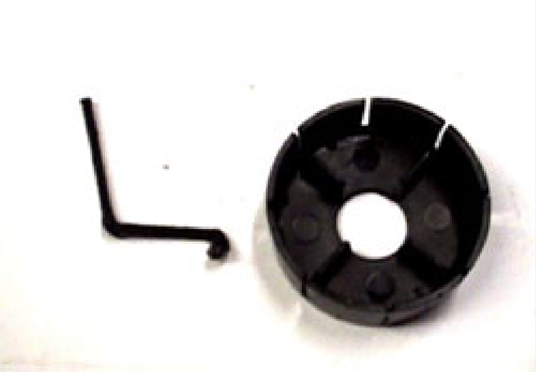
Figure 5: Plastic end cap and stick of blackmatch that are pushed down above the first shot.

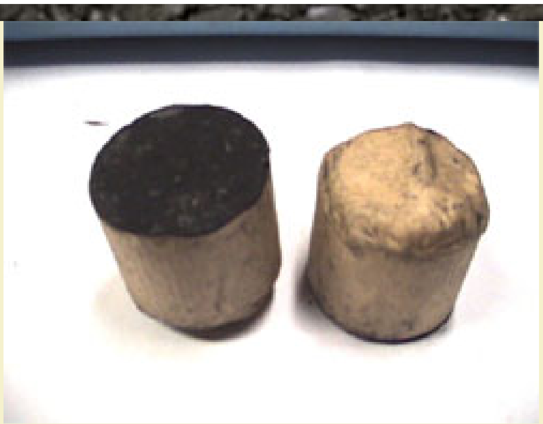

Figure 6: Closeup of the crossette stars.

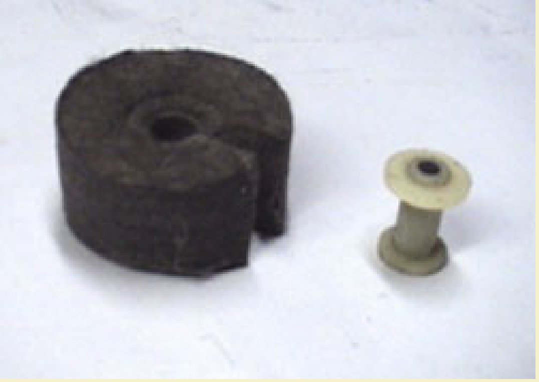

Figure 7: The felt wadding and timer spool used to create the delay between shots.

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AUTOPSY

German Made Class B Rocket

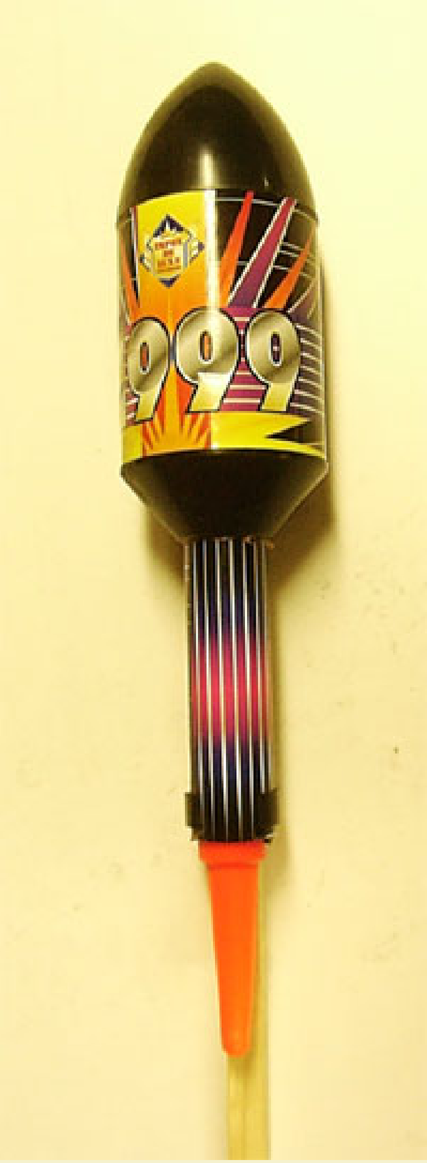

Figure 1: Rocket Specimen.

Manufacturer:	*German, company unknown*
Total Weight:	*389g*
Stick Weight:	*92g*
Stick Size:	*48" long x 9/16" square, spruce*

Engine Specs:

Length:	*4-1/16"*
O.D.:	*1-1/16"*
I.D.:	*15/16"*
Weight:	*100g*

Header Specs:

Length:	*4" long including nose cone*
I.D.:	*3" w/2-1/4" O.D. ball shell inside*
Weight:	*90g facade + 70g ball shell*
Ball Hemis:	*2" I.D., 2-1/8" O.D.*
Paste Layers:	*4*
Stars:	*37g variegated, size range from 3/32" to 7/32"*
Burst:	*13g flash coated rice hulls, 4:1 ratio*

Analysis:
This rocket zips into the sky with a charcoal tail, then immediately breaks into a nice round spread of yellow, red, green, blue and white variegated stars. The only thing it lacks is a brief delay between the rockets flight and the header burst, which creates an unexpectedly early break while the rocket is still moving upward.

The rocket was chosen for autopsy due to its suspiciously large heading. While the rocket did produce a good break, and it is not impossible for a 3 lb rocket to take up a 3" canister shell, there was just an underlying suspicion that this header contained more air than a bag of Doritos from an airport vending machine.

As can be seen in figures 2 through 4, the large 3" dia x 4" long cylindrical heading is a facade for a 2-1/4" paper ball shell. You have to admit, Figure 1 looks far more impressive than Figure 3, which suggests that this rocket was designed for consumer purchase in its country of origin. The amount of flash used in the heading keeps this rocket off the Class C shelves in America however.

The engine consists of an aluminum pipe that is open at one end, with the fuel loaded to within 1/2" below the edge of the open end. A noticeable deformity in the wall of the aluminum pipe may be designed to keep the composition from blowing out the unplugged end of the tube. This engine was encased inside a spiral wound tube that added 1/8" to the O.D. and provided a glueable surface for the plastic components.

The ball shell heading was probably made in China and imported by the German manufacturer. Four layers of typical strip pasted paper enclosed a set of Chinese hemispheres containing a poka style charge of flash hulls and small multi-colored stars. The star compositions all appeared to contain magnalium to brighten the colors. The stars also seem to have been rolled without any cores at all, which helps achieve the maximum burn time from such small stars as these. It is possible that these small core-less stars are byproducts from larger star rolling operations, screened out and put aside for products that require them. The wide variance in size between the smallest and largest stars is further evidence that they may indeed be star rolling scraps. All stars contained a thin 1/64" outer layer of black powder type prime.

While the rice hulls seem to have been coated with flash while wet, there was also a good deal of loose flash amongst the stars and hulls. The type of flash used had a rather slow burn rate, failing to produce the "thump" that faster burning flash creates when small amounts are burned in open air. The type of aluminum used was something similar to American Dark flake aluminum.

The ball shell was fused by inserting several pieces of black match through a tube that protruded through the shell wall. The ball was glued to the plastic flange which was mounted onto the cardboard tube that sheathed the aluminum driver.

Weighing in at only 70 grams, the hobbyist would do well to develop a similar version of this header for use on rockets and girandolas. With no need to impress hapless consumers with illusions, which added an unnecessary 90 grams to the payload of this rocket, such a heading should work well on two or even one pound rockets.

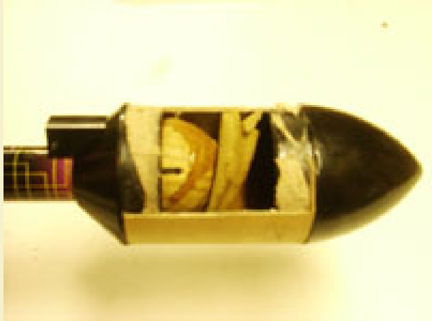
Figure 2: Heading contains over 50% empty space.

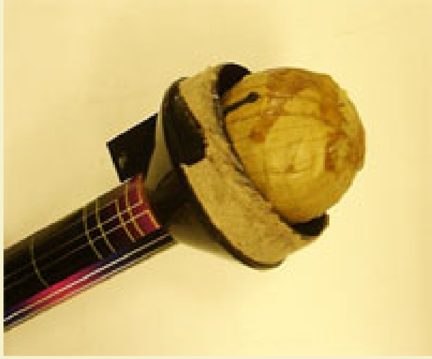
Figure 3: The 2-1/4" ball shell heading, likely made in China.

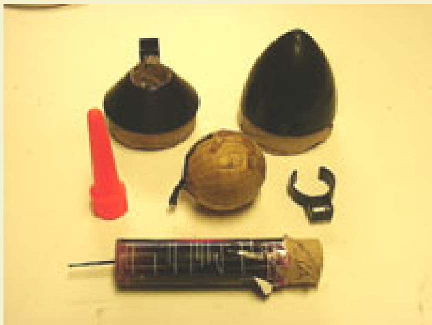
Figure 4: High quality modular plastic pieces for quick assembly.

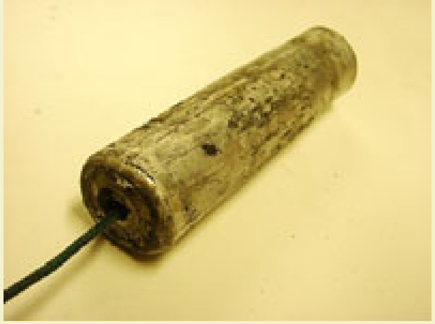
Figure 5: Aluminum engine casing.

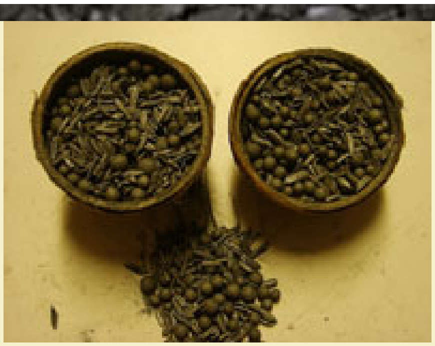

Figure 6: Inside the header, flash coated rice hulls with core-less colored round stars.

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AUTOPSY

STF 4" Red Scrambling Comet Mine

by ***Michael Fales***

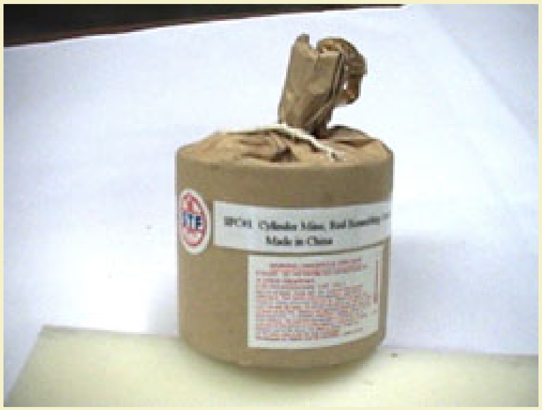

Figure 1: Outside packaging of the mine.

Manufacturer:	*STF*
Total Weight:	*363.5 g*
Lift Charge:	*36 g 4FA*
Stars:	*250g Red Scrambling Comets*
Case O.D.:	*3-5/8"*
Case Thickness:	*1/8"*
Case Height:	*3"*

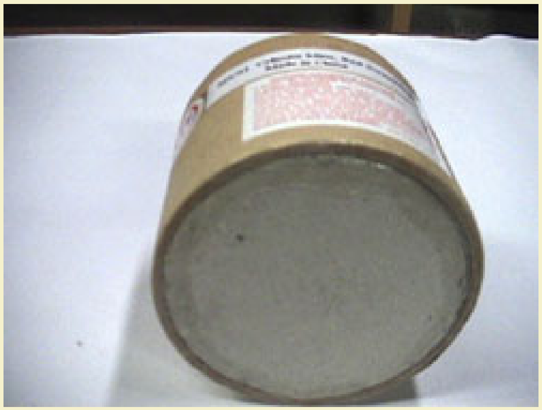

Figure 2: Bottom of mine sealed with a cardboard plug.

Here we delve into a Chinese commercial mine product. Mine construction is not very complicated hence this article will not reveal any ground breaking new construction techniques. However, the scrambling comets provided with this mine are of unique construction and warrant the inspection.

The body of the mine is a thin corrugated tube of 3-5/8" OD and 3" tall. This tube houses all the contents including the lift. A paper plug is placed at the bottom of the tube and glued in place around the circumference of the plug. The mine body tube has one turn of medium weight kraft glued onto the top 1/2" and is tall enough to gather together and tie around the quickmatch leader. Figure 3 shows the wrap partially removed, revealing the quickmatch leader and contents of the mine. The scrambling red comets completely fill the mine to the top of the case.

After removing the comets a perforated plug is shown just above the lift. The quickmatch leader resides along the wall of the tube and the perforated plug holds it in place with a snug press fit. Although it is actually a plug, this style of construction is commonly known as the perforated disk method. Only three holes are provided for fire transfer from the lift and seem sufficient to ignite all the comets. Below the plug a plastic lift bag is tied off around the end of the

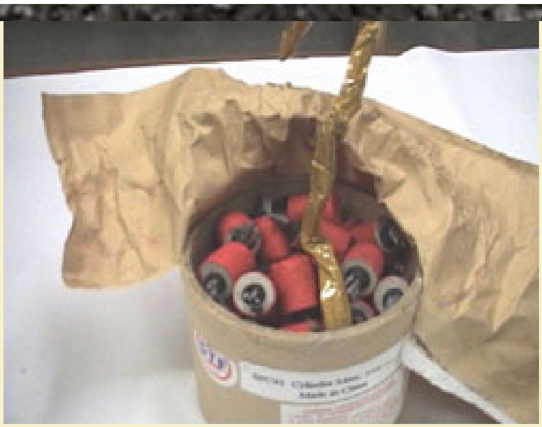

Figure 3: Mine tube is nosed with a few turns of kraft paper.

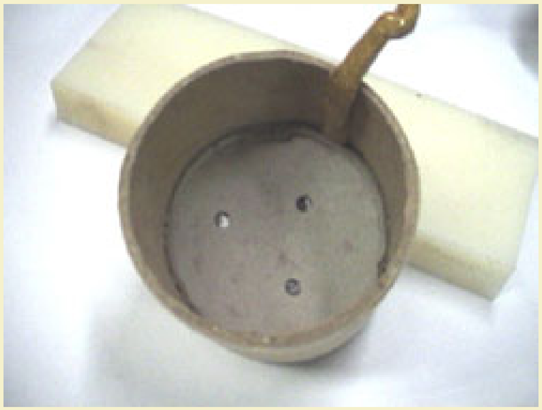

Figure 4: Perforated "piston" disk above the lift charge.

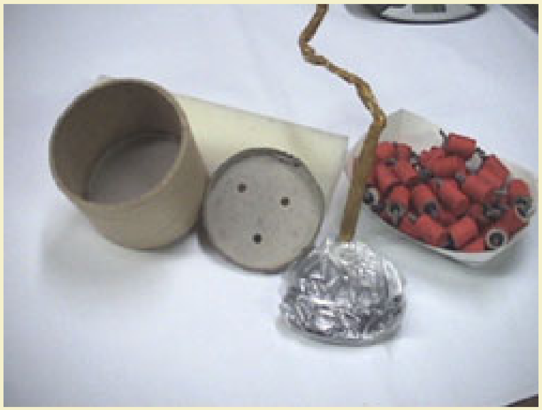

Figure 5: Mine components disassembled.

leader. The reason for bagging the lift charge is to prevent the powder grains from migrating through the holes of the disk and entering into the star compartment, which would diminish the lift charge and under-lift the mine. The lift bag contains 36 grams of 4FA black powder lift. The end of the leader is tied off into the bag and no black match has been bared. It appears enough fire will blast from the match pipe to reliably light the lift bag. This method of mine construction will produce a wider and lower effect than the cup or piston method. This may provide a better display considering the stars are self propelling and will stray from the typical mine pattern.

The real interest here is the construction of the scrambling comets. They are not go-getter type stars or manufactured in a tube at all for that matter. The photograph may appear to be a thick walled tube filled with black powder composition, but they are actually pressed comets that have a primed cavity in the center of one end. This cavity is the primary area of ignition using four strands of Chinese style paper fuse embedded in a black slurry filling the cavity completely. A coating of thick red paint covers the sides and opposite end of the comet to prevent ignition. By burning from the center out at one end, the comet essentially works as a small colored rocket motor with no stabilization. This creates the scrambling effect in the sky. The use of red paint on the red scrambling comets leads one to presume that the paint might possibly match the effect. Unfortunately, no other colors were available for autopsy to confirm this.

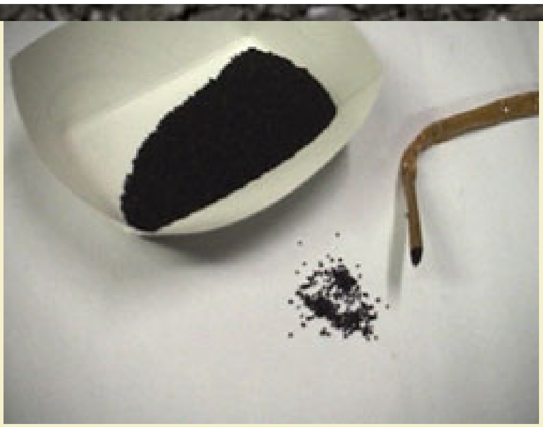

Figure 6: Lift charge and leader.

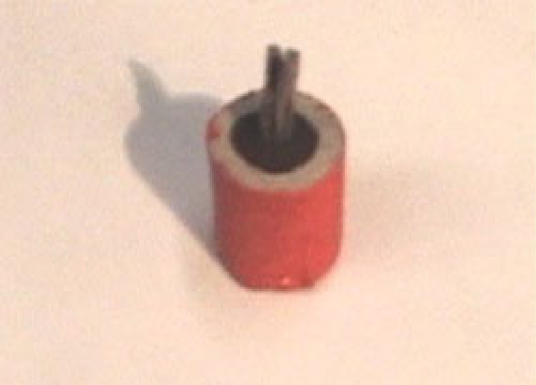

Figure 7: Close-up of scrambling cavity star.

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Build This...

1-3/4" Ball Shells

March, 2004 Issue

Letter from the Editor

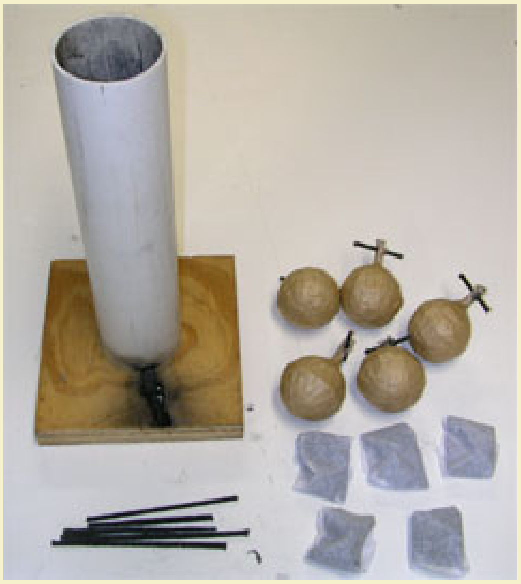
Build This:
1-3/4" Ball Shells

Technique:
Vacu-Form Molding Tips

Tool Tip:
1-1/2" Hemi Molds

Accident Analysis:
Testing Stars

Autopsy:
Brother's 1-3/4" class C canister



Summary:

These small shells are comparable in performance to the widely popular class C "festival ball" type shells. The small amount of materials these little shells consume make them perfect for beginners looking for a first shell project, as well as advanced builders looking for attractive insert shells for larger shells. These small shells also make ideal headings for 1/2" I.D. rockets and girandolas, or they can be combined to produce very attractive cake items that hold their own against commercial class C cakes.

Materials:

- (2) 1-1/2" O.D. paper hemispheres
- (12) 9/16" wide x 6-1/2" long 30lb virgin kraft strips
- (1) 1-3/8" long Chinese time fuse

Tools:

- hot glue gun
- cross match punch
- anvil cutter
- sharp knife or scissors

Unmeasured Materials:

7/32" dia. round stars, 1/2" wide masking tape, hot glue, wheat paste, 2Fg black powder, KP on hulls 7:1, cross match

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1-3/4" Ball Shells...

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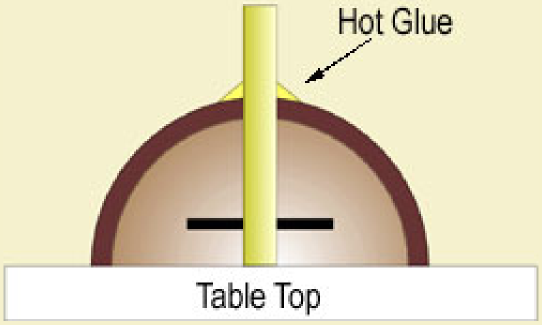

Figure 1: Sealing time fuse with hot glue.

Introduction

There is probably no single item more useful to have under your pyro belt than a high-quality small caliber shell, as the uses for them are many. They can stand alone as single shot reloadable shells that are ideal for testing stars or just having fun. They can be combined into cake items and even multi-shot candle items. They make great upper-layer effects in mines. They also make excellent headings for 1/2" I. D. rockets or girandolas. Small round shells are really the only option for building shell-of-shell ball shells, since cylindrical inserts do not stack efficiently inside a round hemisphere. The small size of the shell described here will allow over 40 of them to be loaded into an 8" shell!

We have all marveled at the ability of the Chinese to produce very small yet effective shells in their Class C products, yet duplicating such efforts tends to be an elusive challenge. Close to 20 trials were conducted in developing the shell described here, and the results are two variations on building them which will produce good results. Both methods use small paper hemispheres made as shown here, and they are strip pasted in the traditional way.

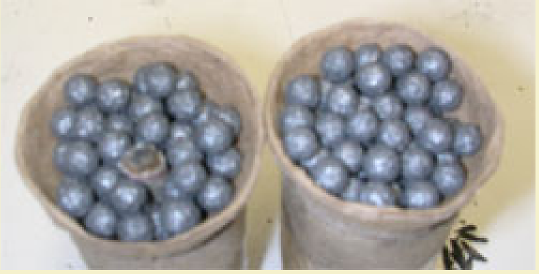

Figure 2: Both hemis filled with 7/32" dia. stars.

Time Fuse

The time fuse is installed as shown in Figure 1. The fuse is cross-matched 1/4" from the end, which results in a better break than if the fuse were simply cut at 45 deg. or slurry primed instead of cross matched.

One hemi in each pair is drilled with a 15/64" dia hole, which is just a hair below 1/4" so that the time fuse will fit snug. The cross-matched time fuse is inserted up through the inside of the hemi, then they are placed onto a table top as seen in Figure 1. Hot glue is used to seal around the time fuse on the outside of the shell, which prevents gas leaks and also prevents the fuse from getting pushed into the shell during lift. For the single-shot reloadable shells being made here, the full time fuse length is 1-3/8" from end to end. Both ends are cross matched 1/4" from the end, thus the timing delay is 7/8" long.

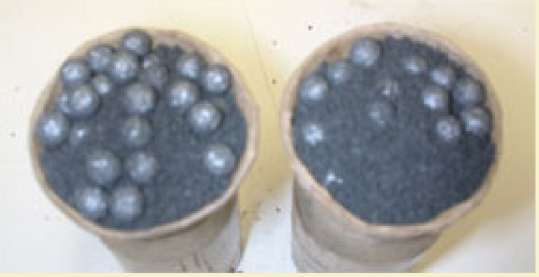

Figure 3: Burst charge of 1/2 TSP 2Fg in each hemi.

Stars

The stars used here are 7/32" dia. solid color stars, which allows a good many of them to fit into the shell. If you wish to use larger stars then it is recommended that they have streamer effects so that the lower star count does not look sparse. Perchlorate/magnalium based color stars are recommended for their slower burn rate and brighter color. Chlorate stars have good brightness but will burn out too fast, while non-metallic perchlorate colors will appear dim due to the small size.

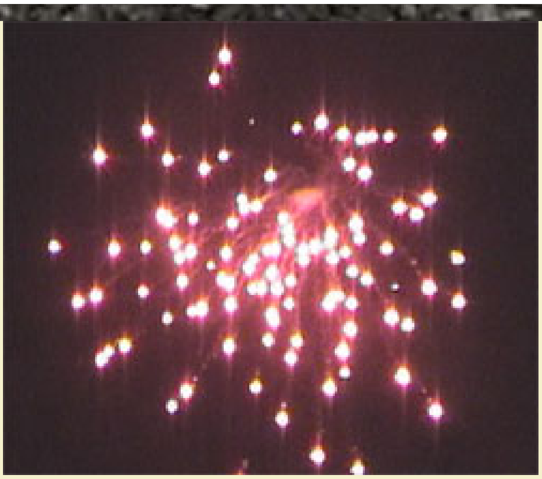

Figure 4: Pattern produced by burst method #1.

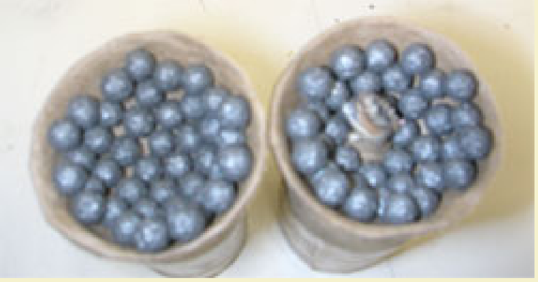

Figure 5: Stars stacked around sides in single layer.

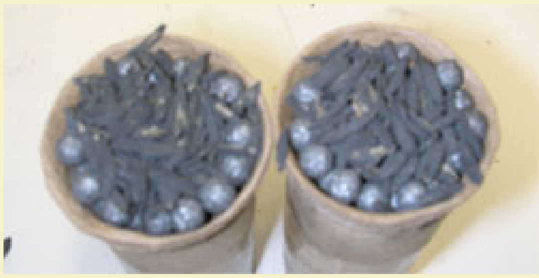

Figure 6: Burst charge of 7:1 KP on rice hulls.

The stars in these pictures appear silver because they have been primed with a mixture of meal and medium flitters aluminum in a ratio of 40 to 1. This creates a hot prime for igniting the MgAl color comp used, and also creates a small streamer effect if the prime is rolled thick enough.

Burst Charge

Two different styles of shell bursts were observed during testing, and since each is attractive in its own way, both types will be described here.

Burst Method 1

The shell burst resulting from this method of loading the shell will result in a smaller yet denser cluster of stars that expand at a slower speed than Method 2. This type of shell is useful for creating a splash of color rather than creating a large, rapidly expanding burst. This type of burst is ideal for insert shells used in mines or shell-of-shell effects, since the bursts will not overlap each other and is more attractive. This method is also faster to construct, which is important if you are making 40 of them for one shell!

Both hemis are simply filled with stars as seen in Figure 2. They are not packed to the rim, but close to it. 2Fg black powder is then used to fill in between the stars, which only requires about 1/2 TSP of powder in each hemi. The 2Fg used here was home made from spruce charcoal and tested stronger than Goex. The down side to this method is that results may vary depending on the 2Fg used. If yours does not work at first, try pasting 4 layers of paper instead of the 3 used here, or add a small booster such as slow flash or whistle mix.

Burst Method 2

This method produces a big break that spreads rapidly, making it ideal for use in cakes and rocket headings. It does not appear as dense as method #1 because there are not as many stars in the shell. The pattern is more noticeably round however, and the shell has less weight for rockets or other self propelled devices to lift.

Both hemis are lined with a single layer of stars in the same way larger shells are built, as seen in Figure 5. This of course requires more time and nimble fingers, so it is only desirable for making small numbers of shells. The center is then filled with KP on rice hulls in a ratio of 7:1, as seen in Figure 6.

Closing

Once the burst charge is loaded, both halves are clapped together in a quick motion to minimize spilling the contents. A slower but cleaner way is to use a piece of cardboard to hold the contents in one hemi as it is inverted onto the other. The cardboard is then slipped out from between them after they are together, as seen in Figure 8. Once together, a band of 1/2" wide masking tape is wrapped one time around the seam as seen in Figure 9.

More...

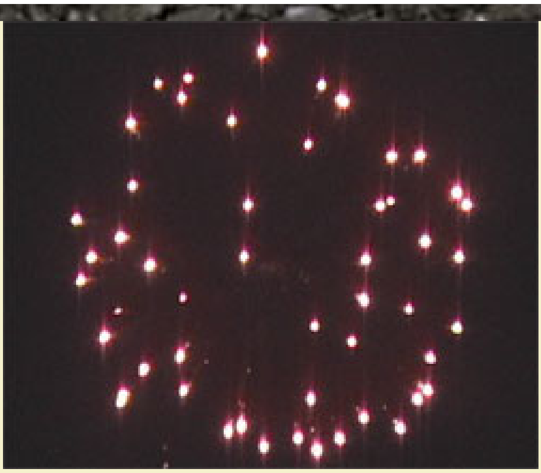

Figure 7: Pattern produced by burst method #2.

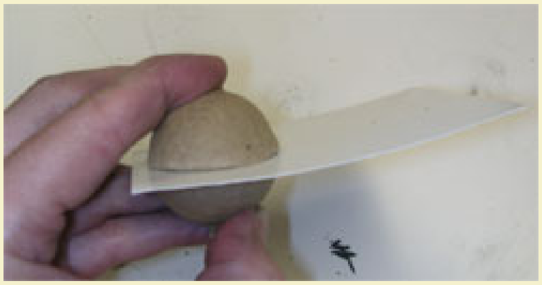

Figure 8: Sliding out a sheet of poster board used to reduce spilling when joining hemis.

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1-3/4" Ball Shells...

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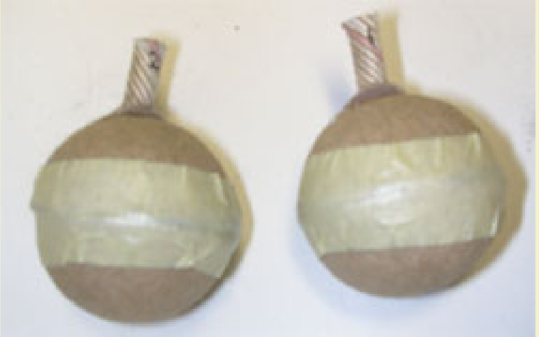

Figure 9: Hemis held together with a band of 1/2" masking tape.

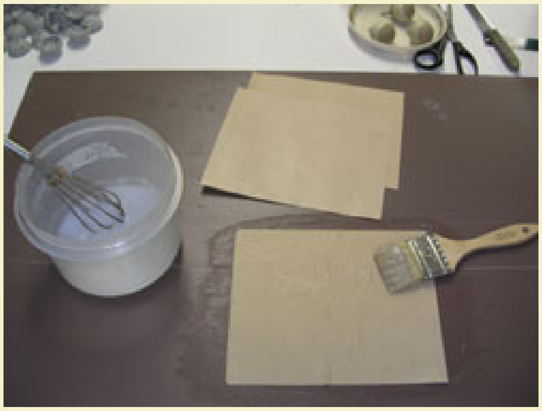

Figure 10: Pasting a 4-sheet stack of 30lb virgin kraft.

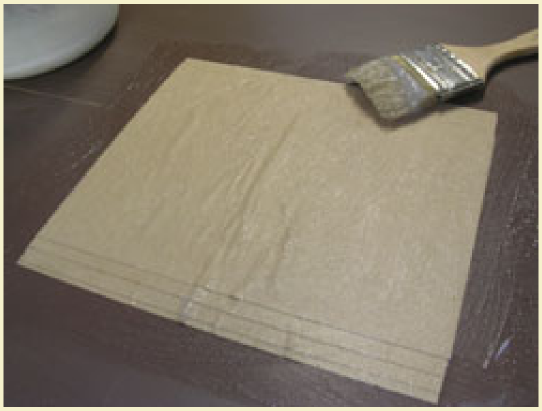

Figure 11: Stair-step alignment of pasted

Pasting

This is the part most people hate about building paper ball shells, and the idea of strip pasting such a tiny shell probably sounds tedious. I have made every effort to make it as painless as possible, allowing you to get through this part in under 10 minutes.

Because it only takes a very small quantity of paste and paper to make one shell, it is a good idea to paste many at once. Wheat paste is desirable over boiling flour, since you can make a small batch of it quickly by stirring the dry powder into cold water using a whisk.

The paper used to paste in these shells is important, as recycled paper in any percentage will drastically effect the break. You want to use only virgin kraft in a 30 lb weight.

We are going to borrow a trick from the Chinese for making the pasted strips we will need. Prepare four sheets of kraft that are 6-1/2" wide by 9" long. The 9" dimension is arbitrary and variable, but the 6-1/2" will be the length of you strips and is a good length. You need to be working on a surface that is "sacrificial," such as a chopping block or piece of wood, because it will get scarred up by the cutting process. The plastic type chopping blocks work good for this application.

Begin by coating your work surface with paste, then stack the sheets of paper one on top of each other, coating each one with paste before applying the next sheet over top of it. Align the sheets in a stair step fashion as seen in Figure 11.

Once the sheets are all pasted, there are two methods you can use to proceed. You can crumple up all the sheets and break-in the paper to get the paste integrated into all the fibers, then flatten it back out and cut your strips. This method saves time in pulling the strips apart because they will finish in a flat state, as seen in Figure 12. The disadvantage is that it is harder to cut the strips once they have been broken-in with the paste.

The other method is to immediately cut the strips after the paper has been stacked, which is how the Chinese do it. The paper cuts much easier this way, but requires you to crumple up all the strips after they have been cut in order to break in the paper. This results in a mass of strips that have to be individually sorted out and laid flat again in order to peal them apart. Breaking in the paper is important for producing soft sheets that lay flat and stick down well, so it is not a step I recommend skipping.

sheets.

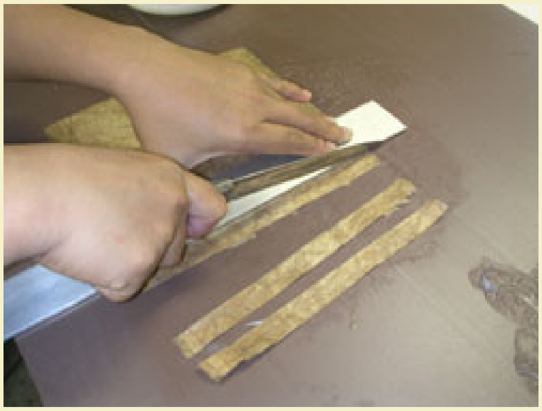

Figure 12: Slicing off 9/16" wide strips with a sharp knife.

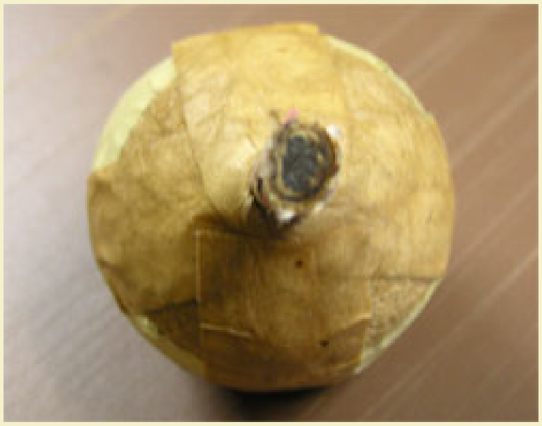

Figure 13: First two pasted strips meeting at the time fuse.

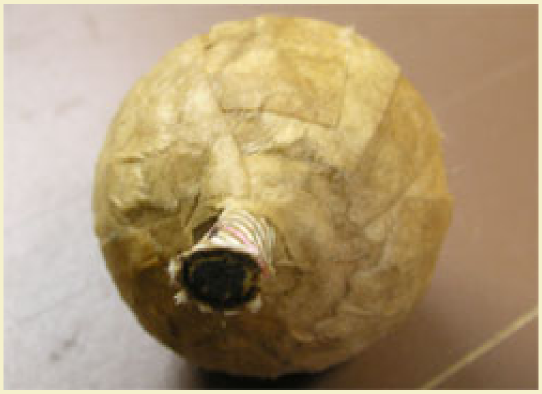

Figure 14: Remaining four quadrants pasted with overlapping strips.

The strips are cut using a thin, sharp knife and a metal straight edge as seen in Figure 12. They should be 9/16" wide in order for four strips to produce one layer on the shell. This way you are producing one paste layer for each set of strips you cut, and you will need three sets to paste in one shell (12 strips total).

The strips are separated and applied to the shell in the pattern described by Shimizu in Fireworks, Art, Science and Technique. The first strip starts at the time fuse and wraps all the way around the circumference of the shell, ending at the time fuse on the other side. The second strips does the same thing, only perpendicular to the first strip. This produces the cross pattern seen in Figure 13. The remaining strips are used to fill in the four quadrants in an overlapping fashion, such that each strip overlaps the strips under it by half. The strips are simply torn by hand to get the desired lengths, which creates a feathered edge that lays down well compared to the crisp edge that would result from cutting with scissors. Figure 14 shows one complete layer pasted onto the shell.

The second layer is pasted just like the first, only running in the opposite direction. Thus the first strip of the second layer would wrap around the seam where the hemis meet, then the second strips would start and end at the time fuse. The quadrants are then pasted in as before.

The third layer is pasted just like the first layer was, thus completing the shell. There now, was that so bad?

Finishing

It is important that these shells are 101% dry before using them. They may appear to be dry on the outside and still have soft paper on the inner layers, which will undermine the confinement strength of the shell and result in many blind stars. A dry shell should be rock hard and resist creasing when pressed against with your fingernail.

The shell is finished by punching and cross-matching the time fuse 1/4" from the end. A tool that makes this step easy can be found here.

Usage

For single firing these shells, a 1-3/4" I.D. mortar that is about 8" long is required. This can easily be made from PVC plugged at one end with a wooden disk, then mounted on a wooden platform.

Rather than attaching the lift and adding a leader to such a small shell, I prefer to bottom fuse the mortar by drilling a 1/8" hole just above the plug and inserting a stick of black match. A lift charge of 5 grams 2Fg is measured and placed on a small sheet of tissue paper, then the tissue is folded up and taped shut to form a square packet, as seen in Figure 15. These are simply dropped into the mortar followed by the shell. The shell can be fuse end down or fuse end up, it will take fire just as reliably in either orientation. The black match will burn through the thin tissue paper and ignite the lift charge quite reliably regardless of how the lift packet is oriented in the bottom of the mortar.

If shooting consecutive shots from the mortar, be sure all glowing embers are extinguished before dropping in a lift packet. Waiting several minutes and swishing dry sand around in the mortar between shots is one way to help clear out burning material. Never look down the mortar after a lift packet or shell has been inserted, least you become the subject of a future Accident Analysis article!

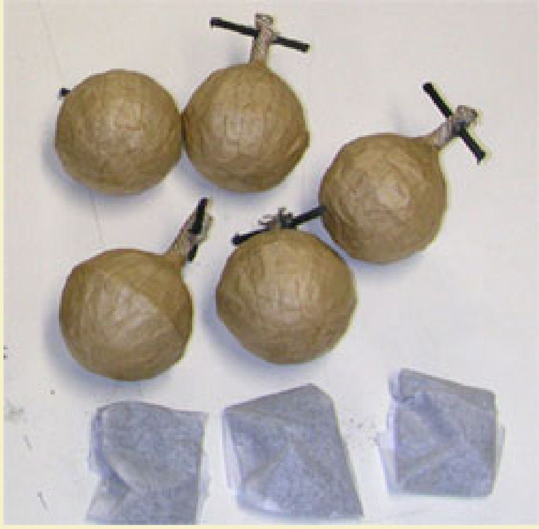
Figure 15: Finished shells with 5g lift bags.

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Volume 4, Issue 2

Tool Tip...

Page 1

1-1/2" Vacu-Form Hemi Molds

Introduction:
While small 1-1/2" diameter plastic hemis are fairly easy to find on the market, the same can not be said for paper hemis. Those wishing to reproduce small paper shells similar to the consumer "Festival Ball" type products are faced with the challenge of finding or fabricating the small set of hemispheres required to make them. This typically involves pasting paper over a golf ball and then cutting it apart after it dries, or alternately trying to press daisy shaped disks of paper into a hemi mold. Both these methods are time consuming to say the least.

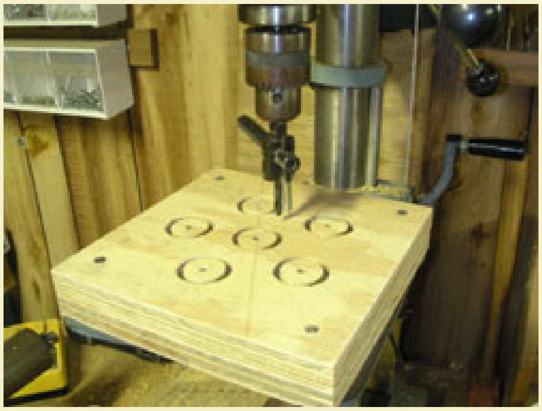


Figure 1: Drilling out large holes with an adjustable hole cutter.

This article shows how to produce a vacu-form mold for producing six hemispheres at once. For those not familiar with the vacu-form method of molding paper mulch, you can read more about the whole process here.

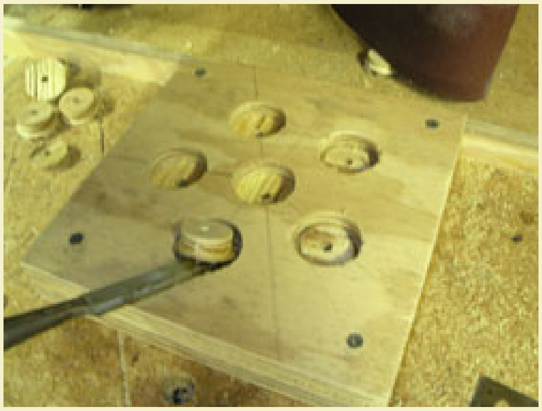
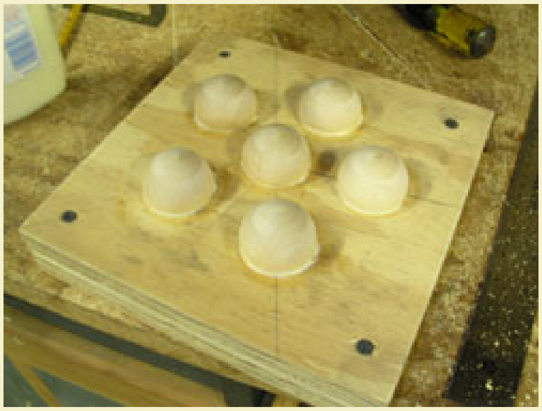


Figure 2: Removing hole centers on male side of mold.

The sticking point for most people who wish to try the vacu-form technique is producing the perforated molds in the various sizes required. The method shown here, engineered by Mike Fales of the Michigan Pyrotechnic Arts Guild, is the easiest way to create these molds. In fact, once you have the tooling done, you can quickly produce multiple copies of the molds and give them to your needy pyro friends!

Constructing the Mold
What we are really doing here is building one mold that produces the final mold of interest, which in turn produces the paper shapes that we want. The basic concept is to heat a sheet of plastic in an oven until it is very pliable, then press spherical shapes into the plastic and allow it to harden. The mold consists of a male plate with hemispheres protruding from it, while the female plate only requires holes that are about 3/8" larger in diameter than the hemispheres used to press the shapes. Lucky for us, these holes do not need to be spherical depressions, they can just be straight holes that run all the way through the plate!



The mold described here is used to press six 1-1/2"

Figure 3: Gluing wooden knobs into the holes to form the male mold.

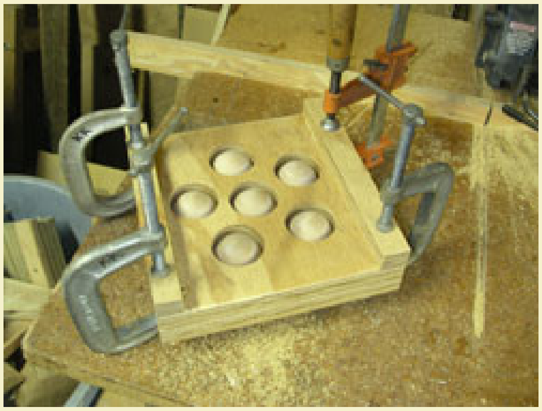


Figure 4: Gluing standoff feet to bottom of female mold.

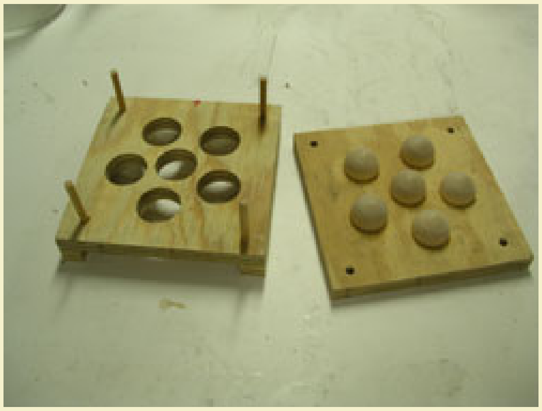


Figure 5: Alignment pins used to keep mold halves in place.

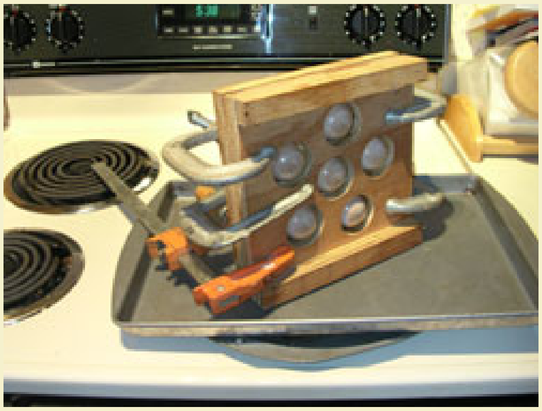


Figure 6: Clamping mold halves firmly together after coming out of the oven.

hemispheres into an 8" square sheet of plastic. The dimensions are designed so that the resulting square sheet can be cut round and mounted into the plastic hemisphere of an 8" shell when finished (see Figure 10).

Because this mold will be required to withstand 400 degree heat for at least 15 minutes, it must be constructed from wood, metal, plaster or something else that doesn't melt. I have chosen wood for ease of construction. Plywood is used for its strength and resistance to warping, although the glue holding it together will melt if left in the oven too long.

Start by cutting two 8" square pieces of defect-free 3/4" plywood. Align both pieces on top of each other and use screws to temporarily hold them together during the drilling operation. Use a black permanent marker to draw a line across the edge of both pieces so you will be able to align the pieces in this same position later.

Mark the center point of the top piece, then use a protractor to measure out five lines around the center with 72 degrees between each line. On each of these lines, mark a spot 2-1/8" out from the center, which is where you will be drilling.

The size of the holes you will be drilling here exceeds the range of spade bits you will likely be able to find. You will need to use a hole cutting type bit such as a hole saw, fostner bit or a ?? bit. I prefer the latter for it's ability to drill a very wide range of holes with only one bit. The adjustable nature of this kind of bit allows you to get any size hole you want. Figure 1 shows this bit being used to drill out the five holes. Make sure the center bit extends beyond the cutting bit by at least 1/4" so that it will mark the center point of the second board. You will stop drilling once you get all the way through the top board.

Once the top holes have all been drilled, separate the two boards and drill the second board to a depth of 1/2". You will need to use a chisel to remove the center plug as seen in Figure 2, since this hole does not go all the way through. The fostner bit has the advantage of removing all the material while still creating a flat bottom, which would be a better choice for this hole.

The wooden spheres used for this mold were purchased from an art supply store. They are 1-1/2" in diameter and are cut flat on one end. They are probably intended to be used as drawer knobs and may be found in hardware stores as well. The flat spot works out nicely for mounting them to the mold

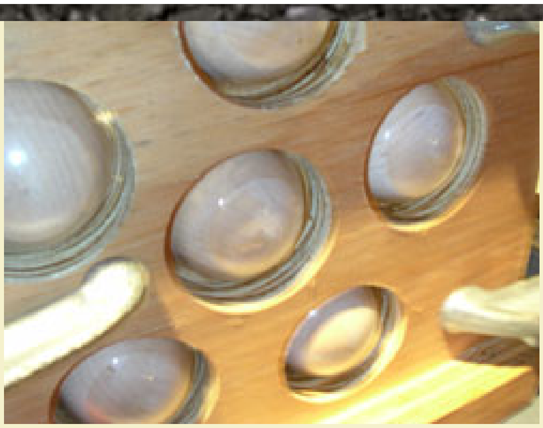


Figure 7: Closeup shows how plastic forms around the wooden balls.

plate. Simply squirt wood glue in the counter-sunk holes and wedge the wood knobs in place as shown in Figure 3.

NOTE: if you want to try the quick-cut method shown at the end of this article, you will need to extend these spheres about 1/8" beyond the center point. In this case you would counter sink the holes to a depth of 3/8" instead of 1/2".

Because the spheres will extend out the bottom of the female plate, you will need to add some standoff legs to the bottom of the female plate, as seen in Figure 4. Gluing strips of scrap plywood here will do the job.

Lastly you will need to add four alignment pins as seen in Figure 5. Clamp the mold plates together and drill a 1/4" hole at each corner. It is recommended that you don't glue these pins in place, as the mold can wedge sometimes and removing the pins makes it easier to get the two halves apart. The pins should be at least 3" long so that they extend above the plate by 2-1/4".

More...

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1-1/2" Vacu-Form Hemi Mold...

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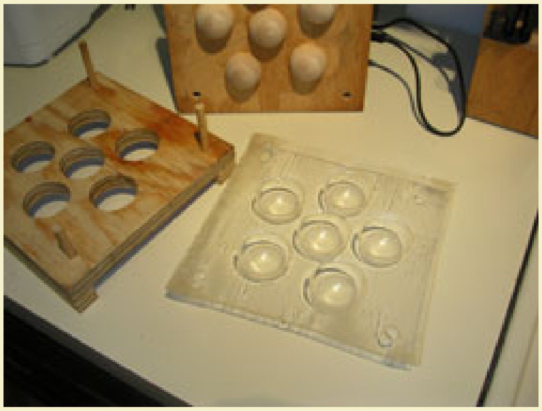

Figure 8: An acrylic mold removed after mold has completely cooled.

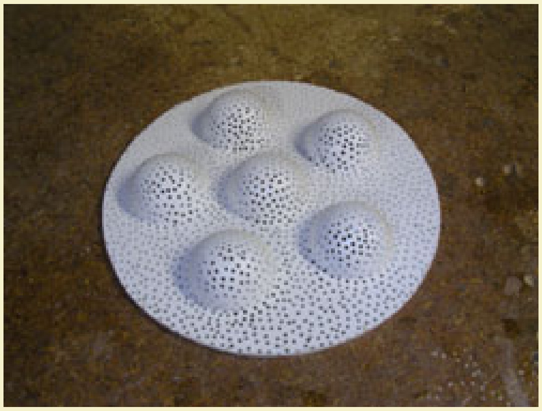

Figure 9: A PVC mold plate after drilling and trimming to fit an 8" shell casing.

Creating the Mold:
This may seem like a lot of work for something that you really only need to use one time to press a single plastic mold, but the time spent constructing this press is actually less than if you attempted to construct the mold out of fiber glass or gluing together pieces of plastic. The resulting one-piece mold is very sturdy and will hold up to the strong suction forces exerted on it during use. If the mold ever does break or if someone you know also wants one, it is an easy matter to crank out another one using the press.

The plastic you use to make your mold can be whatever you have on hand. The 1/16" acrylic sold in hardware stores makes a strong mold, although it is harder to press and drill out than other types of plastic. PVC is a very nice plastic to work with, as it molds easily and drills rapidly without molten plastic clogging the holes. It is available in 1/8" thick sheets and can be obtained from companies that make signs.

Whatever type of plastic you use, you will need to cut it into an 8" square sheet and then drill holes in the corners so that it fits over the alignment pins in your mold. The top mold plate is then placed on the guide pins and the whole apparatus is placed in a kitchen oven to heat up for a good 15 minutes. If you are using acrylic you will need to set the temperature to 425 degrees, while PVC only needs 400 degrees. The plastic will tend to heat more on the corners and some bubbling may occur there before the center is hot enough to press. This part will be cut from the final mold, so it is not a concern.

Once the mold has been cooking for about 15 minutes, it is time to pull it out and compress it. You will want to have at least six C clamps or bar clamps ready to go when you remove the mold from the oven. The plastic sheet will stretch and deform as the spheres are pushed into it, so it is important that the two mold halves be clamped firmly together in order to flatten out any wrinkles.

It takes a good deal of force to fully compress the mold. I prefer to place it on the floor and stand on it until it is nearly fully compressed, then use the C clamps to close it all the way. The mold will be hot, so be sure not to do this on a linoleum floor or you will have a permanent record of this endeavor (speaking from experience here). The plastic will cool quickly, so you have to move fast to close the mold. If it won't go down all the way, return it to the oven for more heating and then try again after a few minutes.

Once you get the mold clamped down solid, the whole thing must be left to completely cool to room temperature before opening it up. If

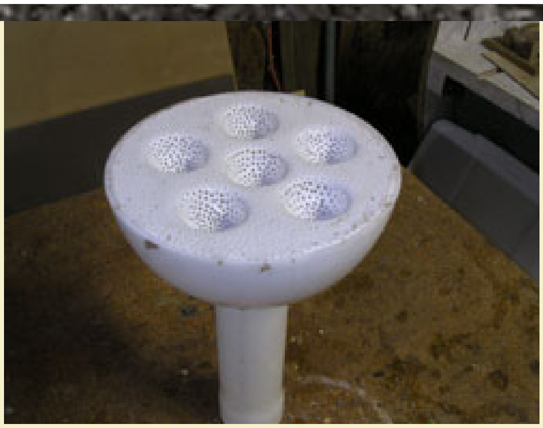

Figure 10: The finished 6 piece 1-1/2" vacu-form mold.

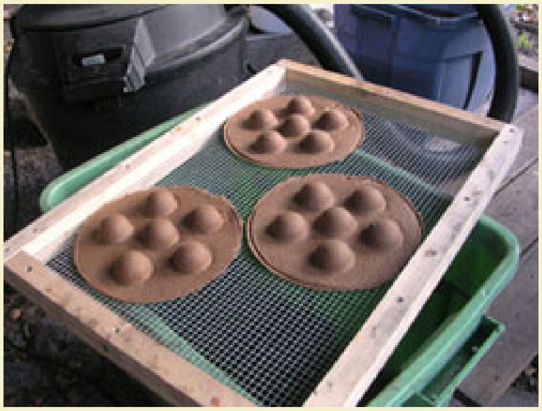

Figure 11: Output of the mold operation placed on drying screens.

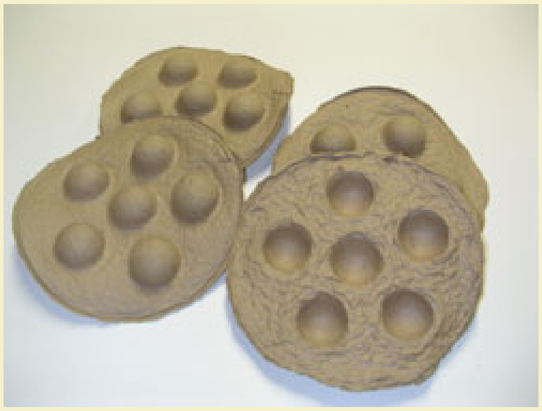

Figure 12: Paper molds dried and ready for seperation.

the plastic is still warm and fluid then it will want to return to its previous flat state.

After a few hours, you should be able to pry open the mold and retrieve the prize, which should look like Figure 8. The plastic tends to grab onto the grain on the plywood, so some prying will be required to get the mold apart.

Next you need to take an 8" plastic shell hemisphere, the side with the indentation on the inside of the rim, and trace the outside of it onto the plastic mold such that the six spheres are centered. A band saw is then used to cut away the excess plastic, then sandpaper or a stationary sander is used to fine tune the edge of the mold so that it fits snugly into the 8" shell piece.

Now for the monotonous part- drilling out the mold. The entire surface of the mold must be perforated with small holes between 1/16" and 3/32" in size. I prefer 5/64" size, but anything in this range will work. If you make the holes too big, then you will get dimples on the outsides of your paper hemis. If you make them too small, you will spend half your life drilling holes because they need to be as close together as you can get them (see Figure 9). A small hand drill is ideal for this laborious task, as you will need to be able to easily hold it in one hand while drilling at various angles. Most holes can be drilled from the back side of the mold, but you will have to drill some of the holes right around the hemi edges from the top side.

Figure 10 shows the finished mold in place. Note that you do not need to glue the mold plate into the housing as long as it is a snug fit and doesn't fall out if turned upside down. The suction force will hold it firmly in place during use. This way you can use a single housing to hold a variety of different interchangeable mold plates. For example, an 8" housing could hold plates for six 1-1/2" molds (2" shell), three 2-1/2" molds (3" shell) and one 5-1/2" mold (6" shell). The molds for 4" and 5" shells are best done with a smaller housing in order to reduce waste from excess flange cutoff.

Using the Mold:
The procedure for producing vacu-form hemis is described here in full. These small hemis are pretty easy to produce, as their small size makes them sturdy and less susceptible to damage when ejecting them from the mold. Their small size makes them a little more difficult to flatten down on the inside after being drawn from the mulch vat. A small ball that just fits inside can be used for this purpose. They only need to be submerged in the mulch vat for a few seconds though, as it is easy to suck up a layer of mulch that is too thick for these tiny shells. When this happens you have to eject the bogus attempt back into the vat and let it dissolve back into mulch, then try it again.

Figure 11 shows some hemi sets ejected onto a drying screen prior to being dried in a DRY BOX. The dried versions can be seen in Figure 12. Cutting the small hemis out from these disks using scissors can be time consuming and annoying if you have to make very many of these, thus it is recommended that the procedure shown in Figure 13 be used if you plan on making a lot. This method requires that you make the extended mold as mentioned on page 1, then make a blade guide out of 1/8" thick plywood to rest the saw or

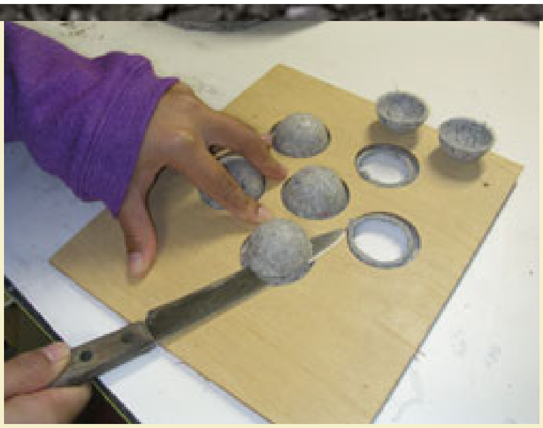

Figure 13: Using a saw or knife to easily trim hemis from mold.

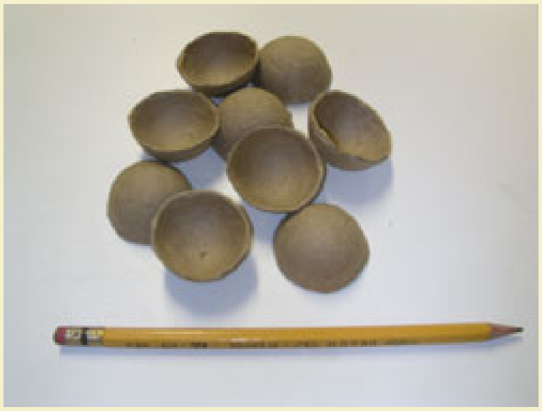

Figure 14: A batch of hemis cut and ready to use.

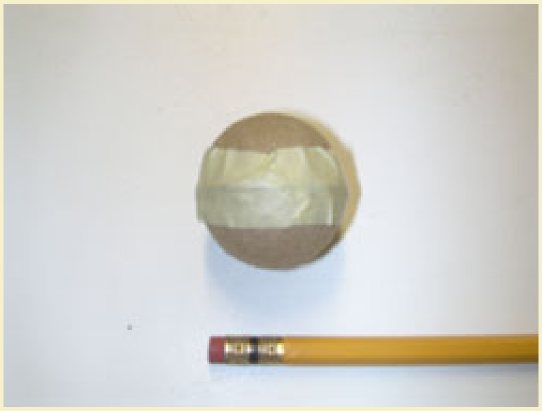

Figure 15: Two hemis taped together to show roundness of the final product.

knife blade on when "beheading" the hemis.

A collection of finished hemis can be seen in Figure 14. If the tolerance on your mold was off a bit then the edges of the hemi mold tend to be rounded over, resulting in a cup-set that can have a walnut like flange around the seam. For a shell this small a defect like this doesn't really matter much. Figure 15 shows a cup set taped together, revealing a respectably round shape!

With small plastic shells costing only 38 cents apiece, one may wonder if making your own paper hemis is worth the trouble. Well, for those not able to purchase plastic, or prohibited from using it or otherwise just opposed to leaving sharp shards of non-degradable plastic all over their shoot sites, this is a viable alternative. The method of forming plastic shown here could also be used to make molds for other types of pyro uses as well, such as rocket nose cones and maybe even cylindrical cup sets similar to the type shown in this months autopsy.

1 lb. Black Powder Rocket...

Page 4

4" Ball Shell Header

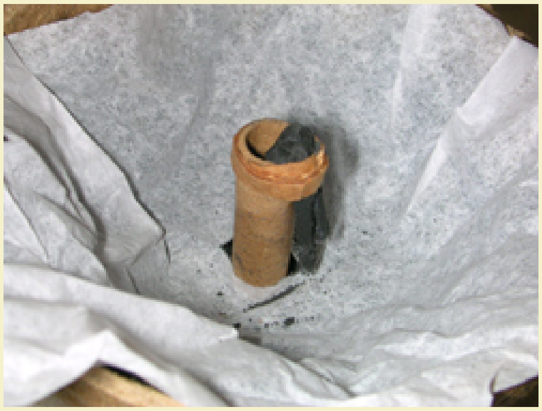

Figure 13: Securing the passfire match into the shell pipette with twine.

Ball shells make ideal headers for rockets compared with canister shells since they produce a larger burst with a lighter payload. The shell shown here is a 4" single petal ball shell, which typically weigh around 250 grams and is about the largest header you would want to try and take up with this rocket. If you want to use a canister shell instead, you will need to drop the size down to a 3" canister in order to keep the payload about the same.

The shell shown here is produced using vacu-form hemispheres, which are lighter weight and produce a more symmetrical burst than commercial Chinese hemispheres. Because the vacu-form hemis get a little damp from the pasted outer casing, they often dry very wrinkly and pretty ugly looking, but don't judge them by their outer appearance because these will blow away any commercial 4" shell in terms of consistent roundness of burst!

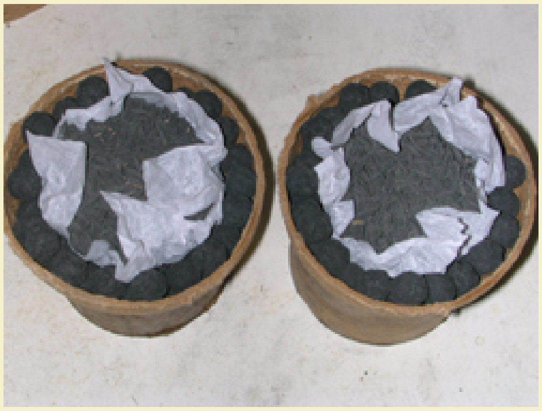

Figure 14: The shell hemis loaded and ready to close.

Unlike regular ball shells, rocket headers do not require time fuse. In place of where the time fuse would normally go, a small hollow tube is inserted so that about 1/2" of it protrudes on the outside of the shell, with the other end reaching the center point of the shell. These tubes can be rolled from a 2" wide x 3-1/2" long strip of 60 lb kraft paper around a 1/4" former rod, which should give you a 2" long tube with a 5/16" outside diameter. Two sticks of thin black match are then routed through the tube, folded down around the inside and tied off as seen in Figure 13. Sometimes the header can get popped off the top of the rocket during the fire transfer, so it is important that the passfire match be secured to the fire transfer tube so that it can not pull out before the fire gets there.

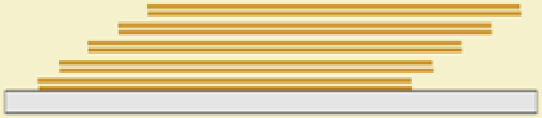

Figure 15: Side view of stacked pairs of pasted strips.

The shell is loaded with a single layer of 3/8" stars, followed by a layer of tissue paper that is then filled with a burst charge of 7:1 KP on rice hulls. Figure 14 shows the loaded hemispheres ready to be closed. A sheet of tissue is placed over one hemisphere in order to keep the material from spilling out when it is inverted and placed on top of the other hemisphere. The shell contents are settled in place by tapping the outside with a wooden stick until the edges of the hemispheres come together. The excess tissue it then torn away and the seem is closed with a band of tape. If you are using the vacu-form hemispheres, then you will need to cover the outside with a layer of masking tape in order to limit the amount of water that leeches into the hemispheres from the pasted outer casing while it dries.

The paper used to paste in this shell is 30 lb virgin kraft, which is light tan in color and is quite strong when it dries. I believe this variety of

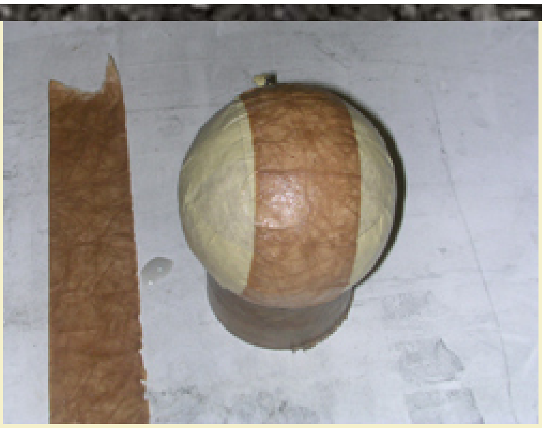

Figure 16: The paste pattern starts with one full wrap around the shells circumference.

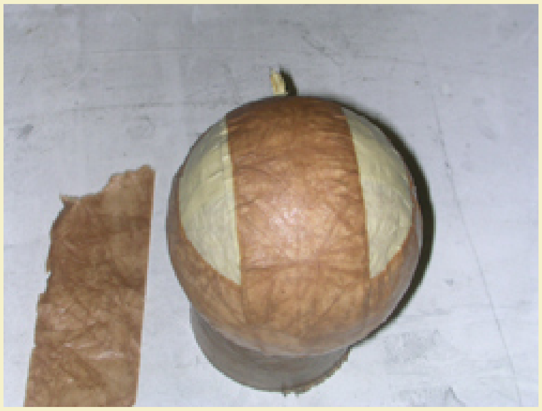

Figure 17: The next strip crosses perpendicular to the first.

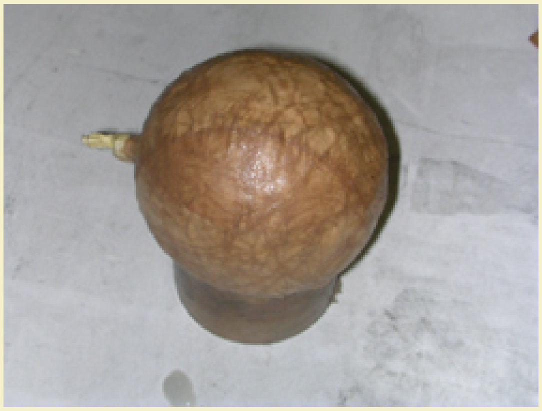

Figure 18: The remaining areas are pasted in with smaller strips .

kraft is known as "blonde" virgin, which lays down good when it is wet. I know what you are thinking… been there, joked about it. But seriously, this is good stuff.

The strips are cut so that the width is equal to 1/8 the circumference of the shell, which is 1.5" in this case. Twenty strips 24" in length are required in order paste in the shell, which are applied in sets of two strips stuck together. So each strip is actually two 30lb strips stuck together when you are applying it to the shell. I like to prepare two sets of five pairs of strips, as seen in Figure 15. Paste is applied to the surface of each strip, onto which the next strip is laid and the process repeated. It helps to offset the ends of the strips in a stair-step fashion so that you can peel them apart again when applying them to the shell. Once two stacks of 10 strips are prepared (five sets of two in each stack), they are crumpled up and squished around in a ball to work the paste in to the paper and "break" the fibers. Once the paste is worked in well, the strips are straightened out again and separated into sets of two so they can be applied to the shell.

Since this is a small caliber shell, you can get away with using a pretty simple pattern of strip pasting. The first strip runs from the time fuse, all the way around the shell and then back up to the time fuse, as seen in Figure 16. The second strip does the same thing, except crossing the first strip at right angles. The paste layer is half completed at this point, now you just tear off pieces to cover the four remaining quadrants and that completes a single paste layer. This shell requires six layers, so repeat the pattern five more times in order to complete the shell. You can rotate the pattern around at different angles if you like, but it really isn't necessary.

Final Assembly

Once the shell is dry, it is ready to be attached to the end of your rocket. First a stick of short black match is secured to the passfire hole in the rocket, using either hot glue or prime to hold it in place. If prime slurry is used, you will need to let it fully dry before attaching the shell.

The ball shell will need to fit flush against the top of the rocket engine, so you may need to trim off some of the fuse pipe if it sticks out too far to allow the engine to seat properly above the clay plug. The easiest way to attach the shell is to use a strong variety of hot glue to seal around the edge of the tube as seen in Figure 19. A fast drying type of glue designed for sealing cardboard cartons can be found at PyroSupplies.com which is very strong and holds the header in place with no further reinforcement necessary. To secure the header even further you can run a few turns of pasted lightweight craft around the seam, tearing it into pleats so that it fits flat against the shell.

The rocket is finished by inserting a hooked piece of visco type safety fuse into the nozzle, as seen in Figure 20. The hook at the end of the fuse prevents it from accidentally falling out of the large exhaust hole where it is inserted. The fuse is pushed up as far as it needs to be to lock it in place. An optional two turns of lightweight kraft can be applied around the end of the tube and tied around the fuse as an additional precaution to keep the fuse from falling out.

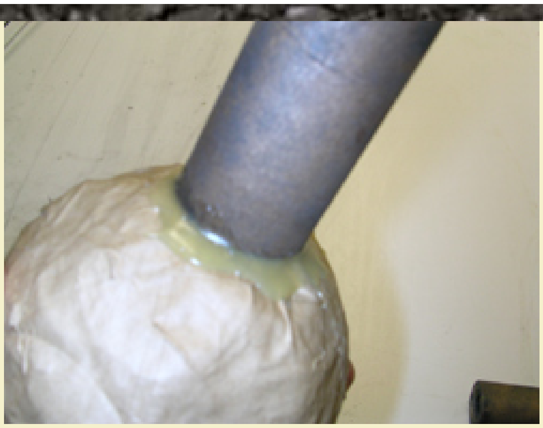

Figure 19: Attaching the dried header shell to the engine using hot glue.

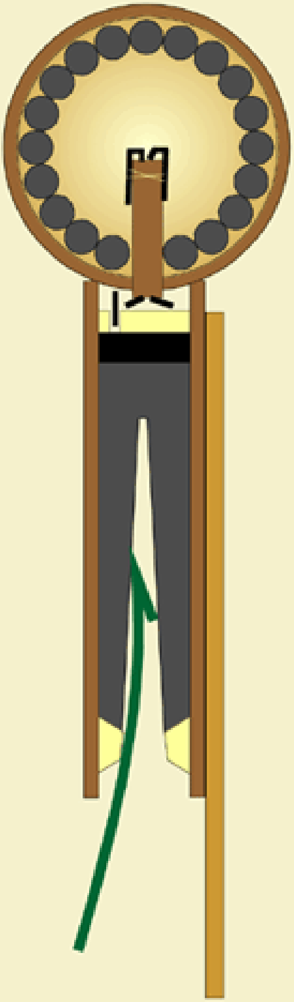

Figure 20: Cutaway view of completed rocket.

The stick for this rocket should be about 5/16" square and 42" long. The length of the stick matters more than the diameter of it, and it can be either round or square. A 1/4" dowel rod would work just as well. I like to cut sticks from cedar, which is a very light weight wood. The weight of the stick doesn't effect how straight the rocket travels, since it is the wind blowing against the stick that keeps the rockets trajectory straight. This is why when you fire rockets in windy conditions the rocket will actually turn and fly into the wind, which is the opposite of what you would expect to happen.

Launching

The easiest way to launch a stick rocket is to drive a piece of metal tubing into the ground. The stick should slide freely inside the tube and the rocket is placed so that the case rests on top of the tube. The tube can be angled in the direction you want the rocket to fly, but rockets usually have a mind of their own and will deviate in unpredictable directions. The spent casing and stick have enough force to dent a car when coming back down, so be careful where you shoot these. Your first dozen rockets should not have a header at all until you can get the engines working reliably without any malfunctions. When launching a rocket with a shell header, always assume that it will malfunction and the header will go off right at ground level, then choose your launch site and protect yourself accordingly.

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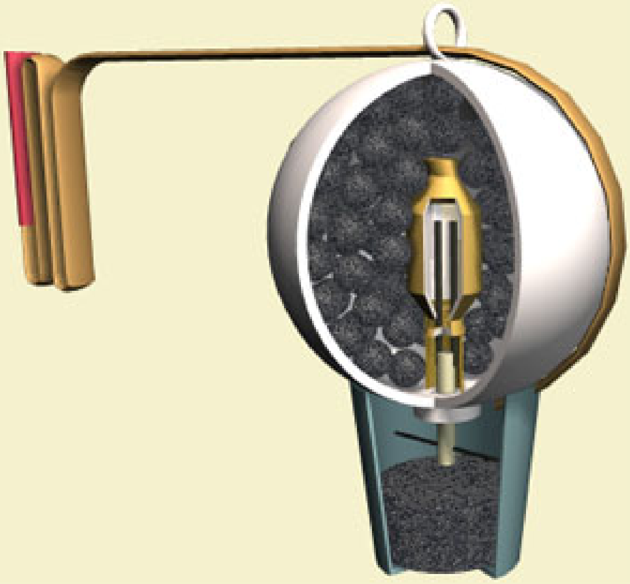
Volume 6, Issue 1

Build This...

4" Plastic Ball Shell

by ***Lloyd E. Sponenburgh***



January, 2006 Issue

Build This:
4" Plastic Ball Shell

Beginner Project:
Film Canister Shells

Design Notes:
Mesh Sizes

Tool Tip:
Poor Man's 3/4" Comet Plate

Autopsy:
7" Red Lantern Shell

Summary:

This plastic ball shell produces a commercial quality break that is comparable with paper ball shells, and it doesn't require any extra steps such as pasting in or reinforcing with fiber tape. Take advantage of the rapid construction allowed by plastic shells and still have pride in the results! This is a perfect first time shell project for new shell builders as well as experienced builders who need a quality break with a short construction time.

Materials:

- Plastic shell halves (with fuse ring & eyelet)
- 120 grams of 4FA black powder
- 5 grams of good 7:3 flash
- 360 grams 1/2" or 3/8" stars
- Methylene chloride, xylene or plastic model glue
- Colored PVC cement
- Good twine
- Penny wrapper
- 3" piece of 1/4" time fuse
- 1-3/8" long 1/4" I.D. tube (4 turns of 70lb kraft)
- Hot melt glue
- 3 oz "Dixie cup"
- 4 inches of visco fuse
- Masking tape
- 36 inches of quickmatch
- White glue

Tools:

- Hot glue gun
- 1" Dia. wooden dowel rod
- Sharp, new single edge razor blade
- Measuring spoons
- Measuring cup (or gram scale)

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4" Plastic Ball Shell...

Page 2

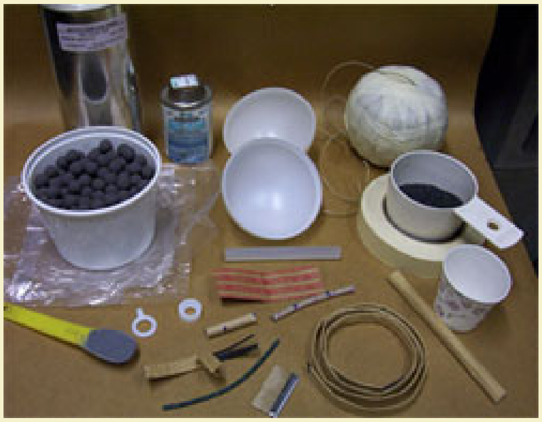

Figure 1: All the materials you will need to build this shell.

Introduction

A beginner at any craft gains a lot from early successes. This project will teach you how to quickly make a high-performance 4" plastic ball (oriental style) shell. It's simple, quick to build, and works better than you'd ever imagine. If you can cut straight with a razor blade, measure length with a ruler, and measure volumes with kitchen tools, you can build a great shell.

Before you do anything else, figure out how the shell parts fit together. The "fuse ring" shown in Figure 2 is used to help seal the fuse entry so fire cannot get in around the fuse and cause the shell to explode prematurely. Soak the concave surface of the ring in a little plastic solvent, or apply an even layer plastic model cement to that surface, then push the ring over its mating stud on the shell, and make sure it seals all the way around, oozing glue out of the joint. Do NOT glue in the "leader hook" yet. It will get in your way during subsequent steps. We'll save that for last.

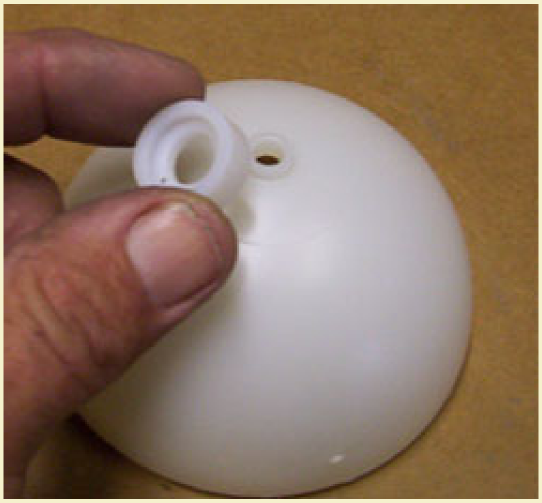

Figure 2: Gluing on the time fuse ring.

Plastic shell halves are not very accurately made. Trial-fit the two halves together, testing new positions until you find a position where the waist joint is as evenly matched all around as possible. This isn't absolutely necessary, but doing this step will help you better seal the shell. Mark a stripe across the joint to help you realign the shell properly later, as seen in Figure 3.

Alright - There are six basic components to a fireworks shell: The shell casing, the leader, the lift assembly, the time fuse assembly, the burst charge, and the stars. In order to keep things neat and simple, we'll assemble the leader and lift assembly as a single unit. We'll make the time fuse and burst charge into a single unit, also.

The burst charge is really two components. First, there's a 5g flash bag (coupette) that creates the heat and initial quick flash to get all the shell contents up to temperature. Alone, five grams of flash won't give as good a break as I like, although it will work with easy-to-light stars.

A secondary 4FA "filler" that gets mixed in with the stars is also part of the burst charge. The BP fill is used to create additional gas during the break. Flash powder is almost a 'negative' explosive, in that most of the combustion products (once cooled and condensed) occupy less volume than the original constituents. Flash gives a sharp hammer-blow break of very short duration. Adding a gas producer lengthens the time the stars are propelled, allowing you to use less flash while obtaining a larger break radius.

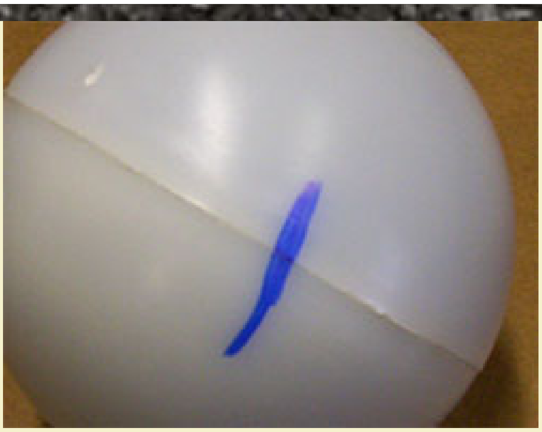

Figure 3: Marking the best aligned position before assembly.

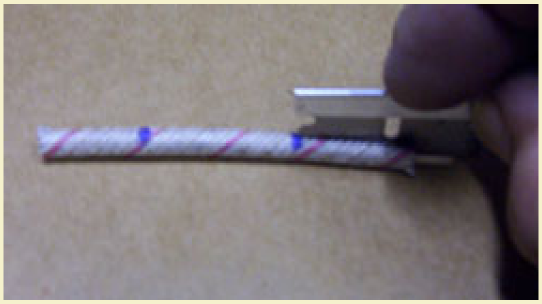

Figure 4: Splitting the flash bag end of the time fuse.

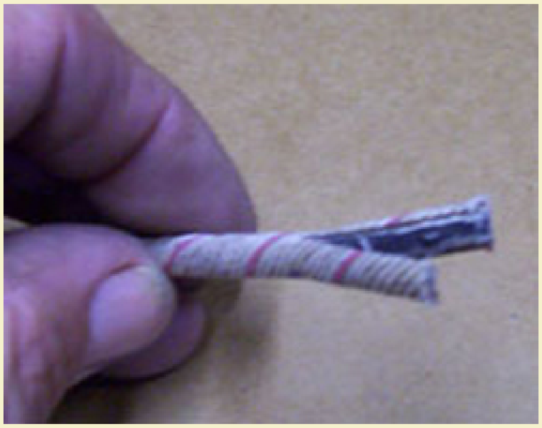

Figure 5: Split fuse after cutting.

This bursting method raises the internal temperature and pressure of the shell so fast that most of the stars are fully lit before the casing fails. I have experienced few problems with star ignition unless more than 7g of flash are used per 4" shell. Spiderweb stars can handle up to 8g!

The outer prime on the stars used in this shell uses a "weak powder", a 78-18-11 hand-mix with +5% dextrin. For hard-to-light cores like high-aluminum content flitter cores, I pre-prime with KP prime (75-15-10 KP,charcoal, red gum with +5% dex). This secondary prime is applied wetter than usual in order to get better integration at the junction between the star comp and the prime.

Time Fuse Assembly

First we'll make the time fuse assembly. This consists of a 3" piece of 1/4" time fuse, marked in the middle a distance equal to THREE SECONDS of burn time. This requires about 1-1/4" distance between the two marks on the fuse shown in Figure 4.

Using a brand-new SHARP razor blade, split only one end of the fuse exactly in half as seen in Figures 4 and 5. Be careful not to let the split go beyond the line marker, otherwise you will shorten your time delay. Gently pry the halves apart enough to insert your "cross-match". Be very careful not to disturb the powder core of the fuse - it's delicate. Slip two 3" long pieces of THIN bare match all the way to the bottom of the slit. Bend them up toward the end of the cut fuse and capture them along their length in the slit.

Now the next part is a little difficult. TIGHTLY HOLD the fuse and match together so they don't slip out of position, then feed the un-cut end of the time fuse through a 1/4" I.D. cardboard tube. While holding the cross match in position, pull it through the tube until the split end of the fuse is even with the end of the cardboard "standoff" tube. Some of the bare black match will (should) still protrude past the end, as seen in Figure 7.

Burst Assembly

Next, we prepare the "flash bag" burst assembly. This is the charge that causes the shell to explode, driving the stars outward. Pleat the end of a penny wrapper so that it fits neatly around the cardboard tube. Slide it down to about 7/16" from the bare-match end, then TIGHTLY secure the wrapper with a clove hitch about 1/4" up from the end of the wrapper. Test the seal… it should be tight, and you shouldn't be able to blow air through the wrapper and fuse. The knot should collapse the tube around the fuse (TIGHT!). Secure the knot with a drop of white glue.

Using a funnel to keep things neat, place five grams of flash powder (that's a barely over level teaspoonful) in the paper bag you've formed. Gently tamp the powder down by lightly tapping the fuse assembly down on your work surface a few times. Close the bag by twisting the wrapper over the top of the flash powder, then tightly secure the twist with a clove hitch. Make this joint as close to the powder as you can without pinching powder in the knot. You want the flash bag to be full of powder without excess air space.

CAUTION!!! Do NOT use scissors for the next step, use only a

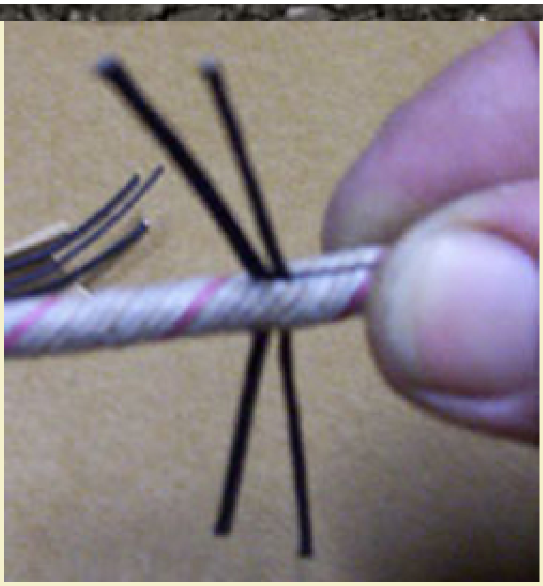

Figure 6: Inserting two strands of black match.

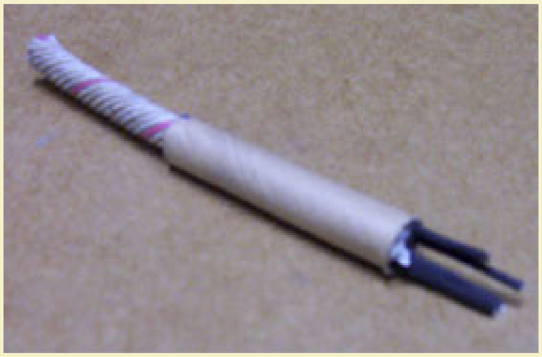

Figure 7: Cardboard tube slipped over the fuse.

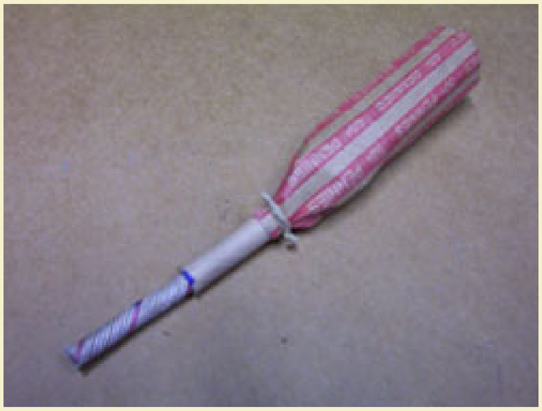

Figure 8: Penny wrapper flash bag tied onto the fuse.

sharp razor. Trim the end of the flash bag about 1/4" away from the top knot to remove the excess paper. Scissors may cause friction that can ignite flash powder if particles get in between the blades!

Next you will insert the time fuse and burst assembly into the plastic hemisphere with the time fuse hole. Apply a bead of hot-melt glue around where the cardboard tube and fuse meet, then insert the fuse into your bottom shell half, carefully centering the fuse/burst assembly until the glue cools. It should look like Figures 10 through 12, being well-centered horizontally and halfway below the "equator" of the shell. When the shell is assembled, the flash bag should be located right at the center point.

When the glue holding the fuse in place solidifies, turn the hemisphere over and fill the empty space inside the "fuse ring" with hot-melt glue, which will seal the gap between fuse and shell. NO FIRE MUST PASS THIS JOINT, or the shell will explode prematurely. Try to avoid bubbles. The glue should be hot enough to "wet" the fuse, which means it absorbs into the paper instead of beading up around the outside.

Loading the Shell

Now we'll prepare and load the stars. First, punch a hole in a plastic sandwich baggie so it will fit around your burst bag. Neatly line the bottom shell half with the baggie as seen in Figure 12.

Using your "top" shell half as a measuring scoop, put an amount of stars in the baggie that will almost reach the middle of the joint between the shell halves. A few stars can stick out level with the top, but none should protrude past the edge of the shell.

Sprinkle about 40 grams of 4FA powder in over the stars, then put another (carefully measured) scoop of stars into the baggie. Sprinkle another 40 grams of 4FA powder onto the new stars, then twist the baggie tightly closed and secure with a clove hitch knot (Figure 14). If you get too few stars, your shell might not burst perfectly symmetrically, but with too many, you won't be able to properly close the shell.

Next you will close the shell using the other plastic hemisphere. Take extreme care not to let any part of the baggie get caught in the joint between the two shell halves. You can tell if you've got the right amount of stars when you first try to close the shell. If - when you squeeze the halves together TIGHT - they almost close, but not quite, you've got about the right amount. Then, while squeezing hard, gently tap around the shell halves with a wooden dowel to jostle the stars into a tighter fit. When the shell closes properly, **there should be NO gap at all in the joint**, and NO stars should "rattle" inside when the shell is gently shaken (you should only hear loose 4FA powder). Don't bang hard on the shell with the dowel rod. If it simply won't close tightly, re-open the shell, remove a few stars and then try again.

More...

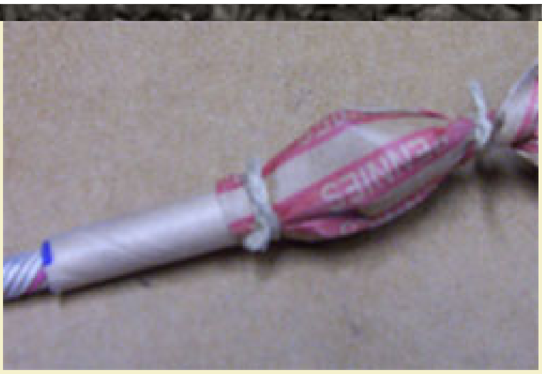
Figure 9: Flash bag loaded and tied shut.

More Pictures

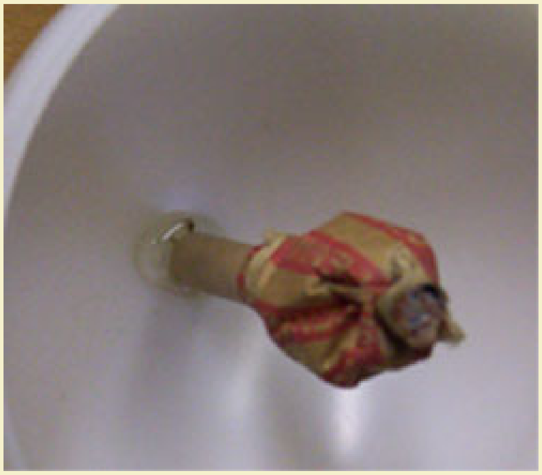
Figure 10: Fuse assembly glued into the shell.

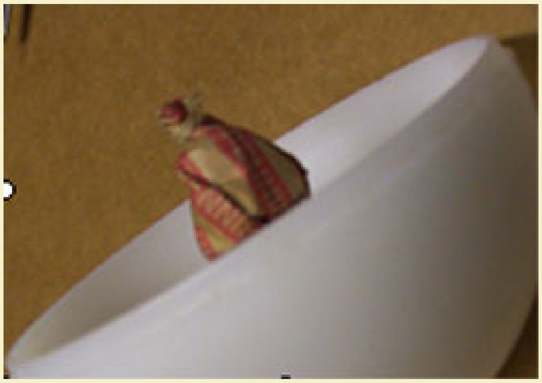
Figure 11: Side view to show flash bag placement at center.

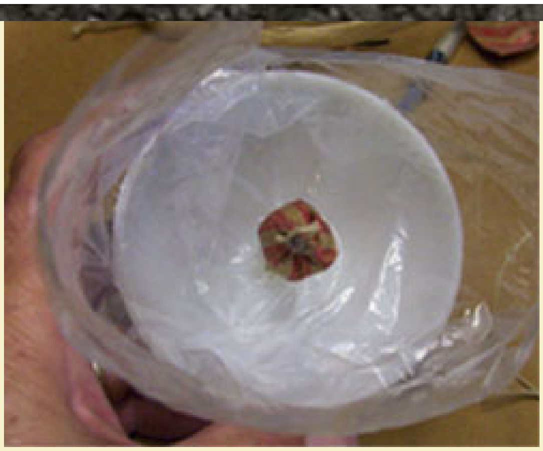

Figure 12: Plastic bag inserted prior to loading.

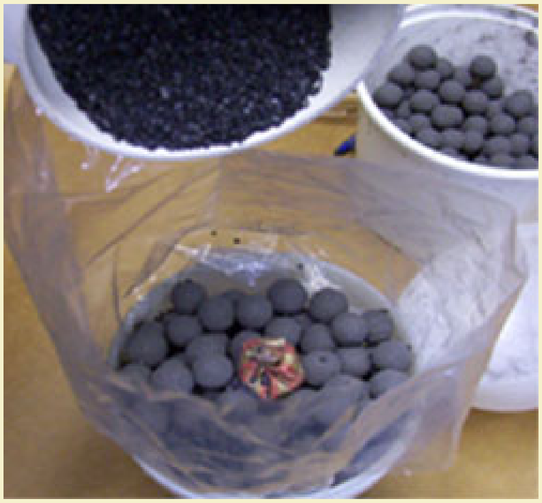

Figure 13: Adding 4FA after half the stars are loaded.

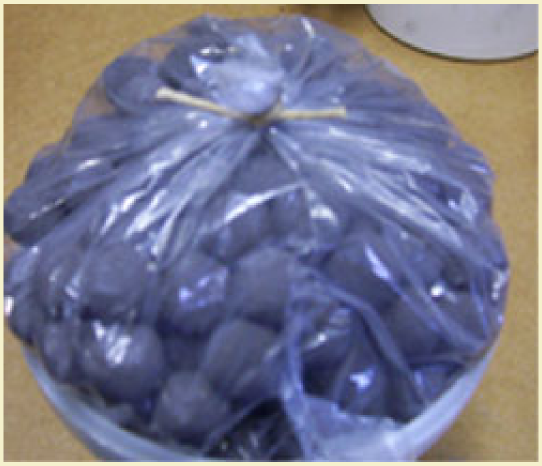

Figure 14: Second half of stars are loaded and tied shut.

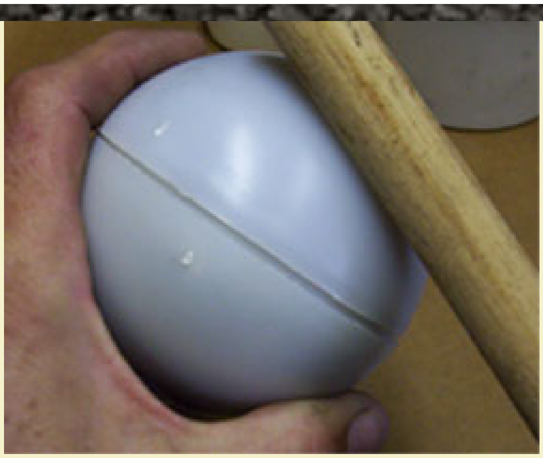

Figure 15: Closing the shell by tapping with a rod.

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4" Plastic Ball Shell...

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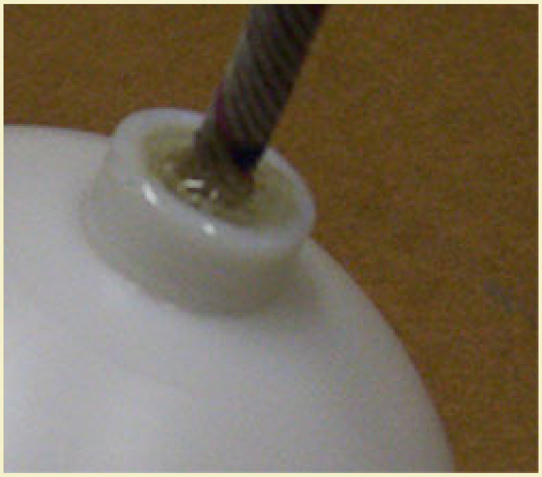

Figure 16: Close up showing glue seal around time fuse.

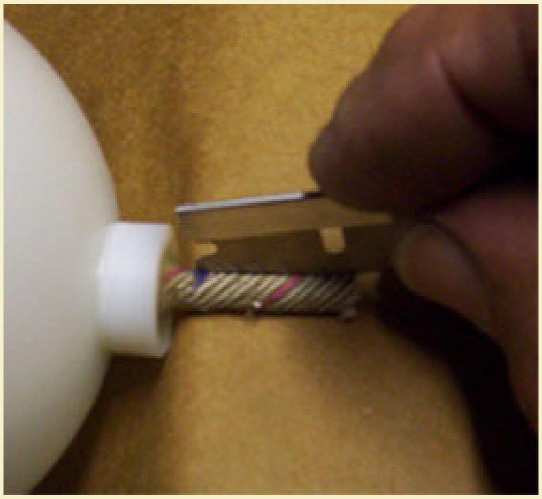

Figure 17: Splitting the outside end of the time fuse.

Once you have the shell closed properly, hold on tight to keep the shell tightly squeezed shut, and flood methylene chloride solvent around the equator to glue the halves together (don't wipe it on, liquid must flow into the joint). DON'T stop squeezing until the solvent dries! When you're done, you should see no gap and no pinholes in the joint. Melted plastic should ooze from the equator all around.

Now is the time to glue in the "leader hook" into the top hole of the shell. Use solvent, like you did with the fuse ring. Soak the tip for a few seconds before inserting it.

It's not a bad idea to label your shell now, before you forget what's in it!

To seal the joints, apply a thick coating of colored PVC cement to the equator joint and around where the leader hook inserts into the top half. Again, don't wipe the cement thin, but paint on a thick, uniform layer. Set the shell in a stand to dry thoroughly before the next step. AFTER DRYING, CHECK FOR PINHOLES, and re-seal them with a little more PVC cement, if necessary. Make sure the cement is completely dry (hard) before proceeding.

To complete the fuse assembly, you must "cross match" the time fuse so it will take fire from the lift more easily. Split the fuse right up to your mark the same way you did for the burst bag end. It's easiest to lay the fuse on a table edge to do this, as seen in Figure 17. Insert two pieces of bare black match in the slit, and tie the slit closed TIGHTLY against the cross-match with a clove hitch. Secure the knot with a small drop of white glue, then trim the excess twine. The match should be held snugly in the slit. Check it, and re-tie if necessary.

Lift and Leader Assembly

Let's discuss measuring black powder. Most people aren't aware that the apparent density of black powder is about the same as water. This means you can "weigh" powder with common kitchen measuring tools. For instance, an 8-ounce measuring cup of powder weighs - Eight ounces! A tablespoonful weighs about 15 grams. A teaspoonful weighs about five grams. This shell isn't too critical about measurements, so long as you're reasonably careful. You can use volume measures to "weigh" your powder and burst charges. If you wish to be more accurate, weigh them on a gram balance instead.

Your leader consists of a 33" long piece of quickmatch, some visco fuse (green fuse), and a safety cap for the fuse. The lift assembly is a 3oz Dixie cup with the lift powder contained in a plastic sandwich baggie.

First, measure 35 grams of 4FA lift powder. That's TWO level tablespoons plus ONE level teaspoonful. Put the lift into one corner of a lightweight sandwich baggie, as seen in Figure 19. Draw the baggie up, and cut it off with about 1-1/2" clear of the top of the powder.

Bare one end of your leader quickmatch for about 3/4". Place the bared end of the leader into the powder in the bag, then draw and twist the baggie around the leader. Secure it tightly with a clove hitch. Trim the twine short (but not too short), to make it neat. Secure the knot with a small drop of white glue.

Insert a 4" piece of visco fuse into the other end of the leader - making sure it goes into the space with the black match rather than between the layers of paper. Secure the visco to the leader with a clove hitch followed by a few turns of masking tape as seen in Figures 21 and 22. Cap the fuse (to protect it against sparks in the field) with a piece of light paper tubing long enough to cover the entire green fuse. Fold the end over and crimp it to stay shut. Finally, secure the leader match into the "lift cup" with a dab of hot-melt glue. (TAKE CARE not to get the hot glue on the plastic baggie or it'll melt a hole right through it!)

Invert your lift cup over the time fuse, so it's well centered on the bottom of the shell, and so the leader lines up with an "open" side of the leader hook. Attach the cup to the shell with a bead of hot glue using plenty of glue, then let it cool THOROUGHLY before you let go of the lift cup (otherwise it WILL slide out of position).

Thread the end of the leader through the leader hook as seen in Figure 27. Finally, lay a bead of hot-melt on the inside surface of the leader where it will curve around the shell, and carefully flatten it out onto the surface of the shell, so it doesn't protrude any more than its own thickness.

You just finished your shell! Wait until you're sure all the glue and cement is dry. Fire it safely according to proper shooting protocols, and enjoy your work!

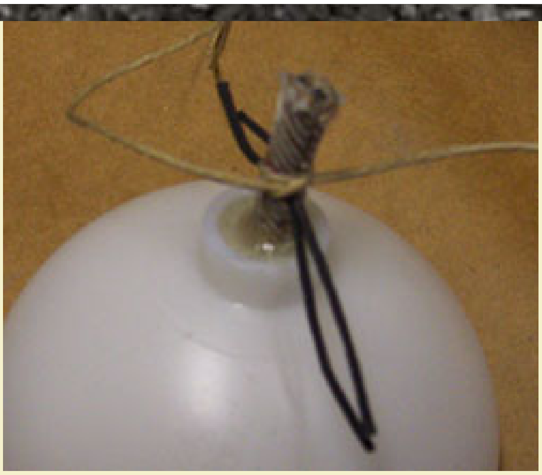

Figure 18: Securing two strands of cross match.

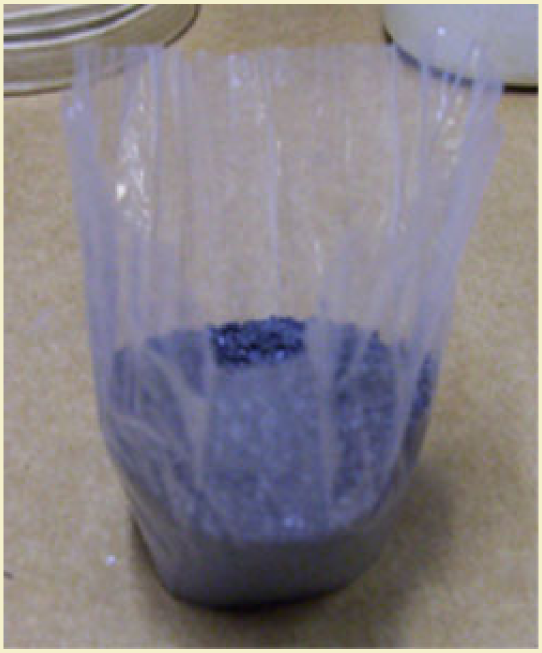

Figure 19: Loading 35g of 4FA lift powder into plastic bag.

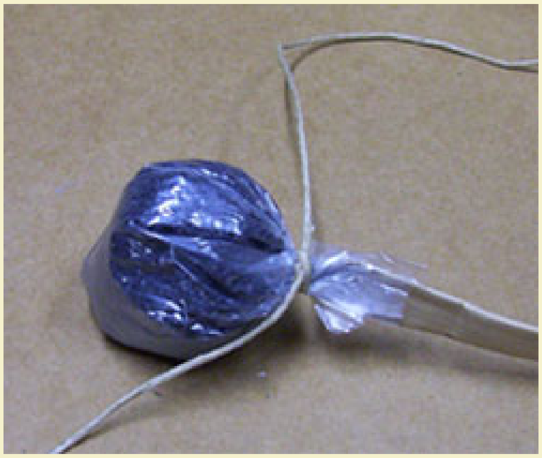

Figure 20: Quickmatch leader tied into lift

bag.

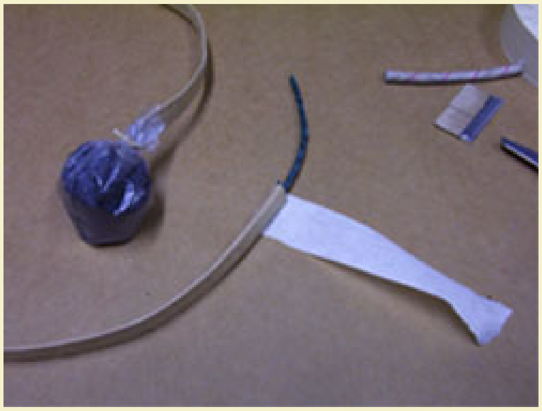

Figure 21: Securing visco into leader using masking tape.

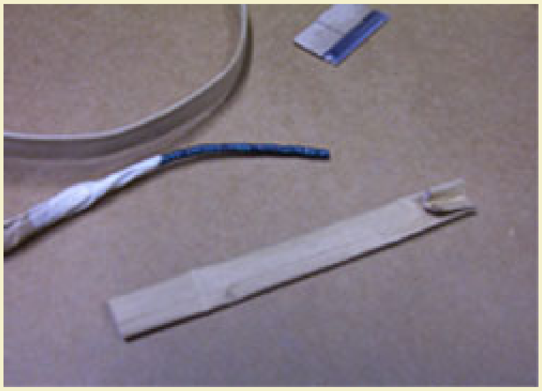

Figure 22: Tape is twisted to form a good seal.

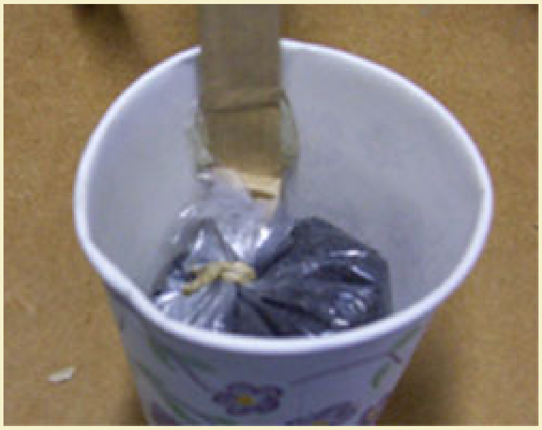

Figure 23: Lift assembly loaded into a paper cup.

Lloyd Sponenburgh (left) working with a student during his shell building seminar at the 2005 Florida Fall Fireworks Festival. Lloyd spent the time to write this article and print it out in full color for all class participants to have as a reference. Sixty shells were built as described here (mostly by first time builders) and fired as part of a larger display that night. All sixty shells worked flawlessly.

More Pictures
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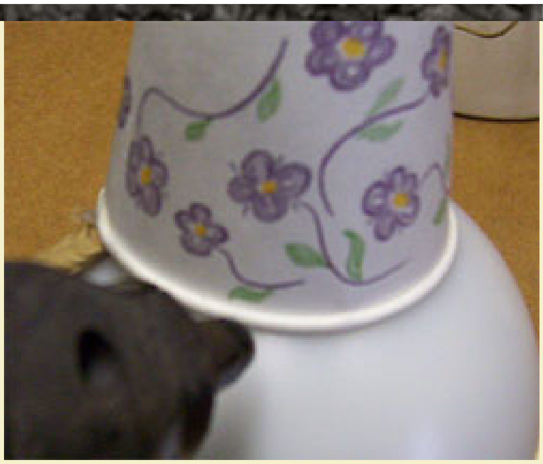

Figure 24: Paper cup glued onto the bottom of the shell.

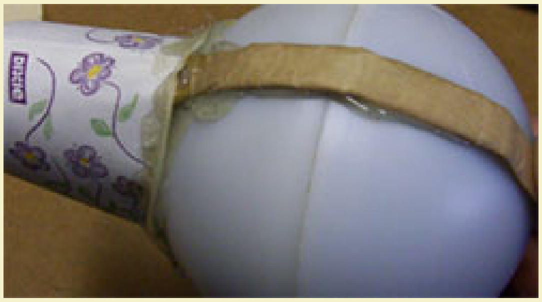

Figure 25: Leader runs up through the plastic eyelet.

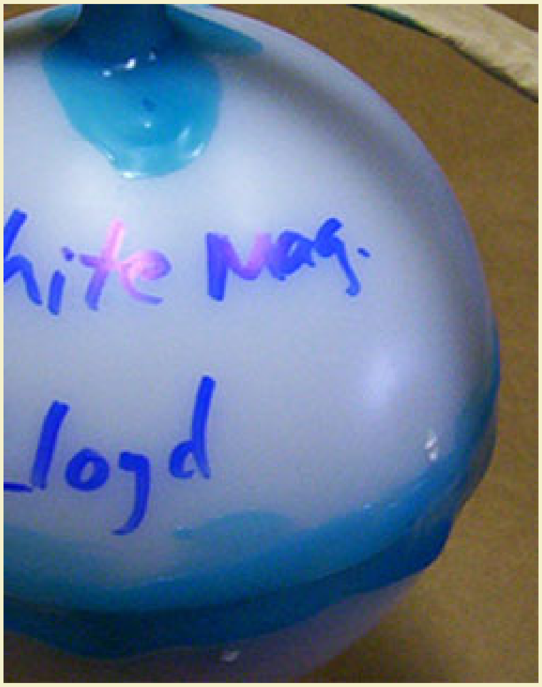

Figure 26: Blue PVC cement used to seal joints.

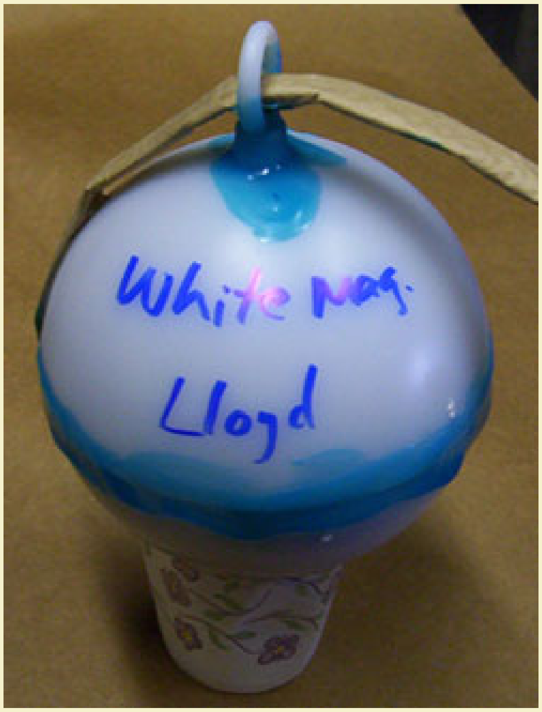

Figure 27: Finished shell ready to fire.

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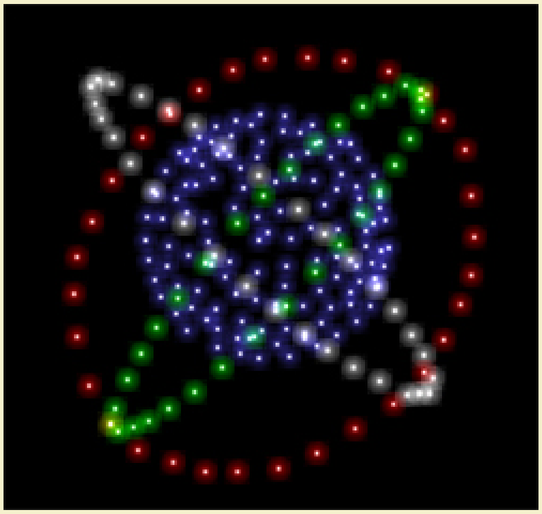
Volume 7, Issue 1

Build This...

6" Atomic Pattern Shell

by ***Jeff Doty***



January, 2007 Issue

Build This:
6" Atomic Pattern Shell

Beginner Project:
Mini Girandola

Technique:
Gummed Tape Ball Shells

Tool Tip:
Gummed Tape Dispenser

Gallery:
4F 2006

Summary:

Jeff Doty is one of the few domestic commercial ball shell builders in the U.S., and his impressive shells often take first place at PGI conventions. This month we are lucky enough to have Jeff reveal his secrets to building what is perhaps the most difficult of all pattern shells: the triple ringed "Atomic" shell. Saturn shells are hard enough to make, but getting three distinct rings on three separate axis to intersect around an inner petal is even harder. The techniques shown here can be used for other types of ring shells and double petal ball shells as well.

Materials:

- (1) set of standard 6" paper hemispheres
- (1) 3" paper or plastic hemisphere w/ 1/2" hole
- 1/4" Clothes line rope (approx. 29 inches)
- Time fuse (2" long)
- 3/8" x 2.5" long Paper tube
- Black Match (approx 4-3/8" long)
- 3/8" Stars: Approx. 34 stars/ring plus 3 oz for the nucleus
- Approx. 1 lb. of KP on Rice Hull burst
- Tissue Paper: 2 pieces 7" x 7"; 1 piece 20" x 20"
- Masking Tape
- Strapping (filament) Tape
- Hot Melt Glue

Tools:

- Wooden Dowel
- Hot Melt Glue Gun
- Felt Tip Marker
- Scissors

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Volume 7, Issue 1

6" Atomic Pattern Shell...

Page 2

Introduction

Most displays of fireworks will include a few pattern shells. The more common type of patterns seen are two-dimensional and include Hearts, Smiley Faces, and Spirals. These are relatively easy to make and, as long as they orient properly, receive good crowd reaction. The problem, of course, is that if they don't orient properly, the pattern can look very distorted or even look like a straight line.

Other pattern shells are three-dimensional. These include Hourglass (or Bow tie) in Ring, Saturn Shells, and Atomic Patterns. An Atomic Pattern with Nucleus is probably the most difficult to make. While the Nucleus is just an inner petal and, therefore, straight-forward to make, getting the three orbital rings to align properly with respect to one another, is a challenge. This article will include some tips that will help you meet that challenge. While the article is for making a 6" shell, the techniques are easily transferred to larger shells.

Time fuse

I use a 2" piece of time fuse that has been cut flat and primed on one end. The primed end is then slipped and tied into a paper tube that is about 2.5" long and 3/8" in diameter (Figure 1). A piece of bare match about 4-1/4" long is folded in two and stuffed into the tube to transfer fire from the time fuse to the burst in the center of the shell.

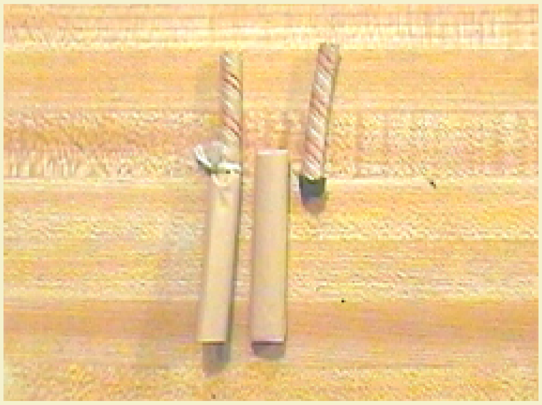

Figure 1: Preparing primed time fuse with an extension pipette.

3" Hemi for Nucleus

To form the nucleus, a 3" hemi is used to mold the burst. Strawboard hemispheres are notorious for turning into football-shaped hemis over time. Since this 3" hemi can be used over and over again to make inner petals, it's best to use a plastic hemi that will keep its shape. However, a strawboard hemi can be kept round by hot-melting a disk into it (Figure 2). Since the hemi needs to be slipped over the fuse and extender, a 1/2" hole is drilled in the center of the hemi.

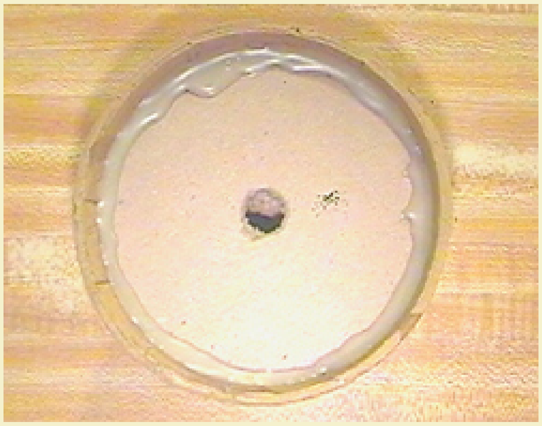

Figure 2: A 3" paper hemi to be used as a cavity former is reinforce with a cardboard disk to prevent warping.

Take a piece of tissue paper, 7" x 7", crumple it up to make it pliable, and wrap it around the 3" hemi, flattening out any wrinkles (Figure 3). This will form the nucleus of the atomic pattern. When working on the fused hemi, you'll need to make a hole in the tissue paper for the fuse extender. Make sure the hole is large so that the tissue won't get caught between the extender and the hemi. If it gets caught, the tissue paper may lift out when you remove the hemi to make the nucleus. Set aside the covered hemi for use later.

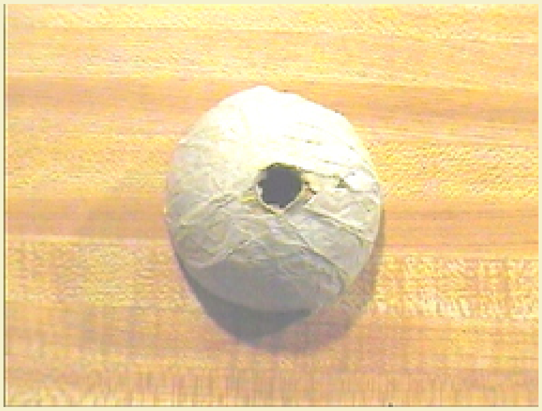

Figure 3: The cavity former is covered with

Marking the Hemis for the Rings

One ring will go along the rim of the hemi, as in the Saturn shell. The other two will be in the two planes that are 90 degrees from the rim tissue paper.

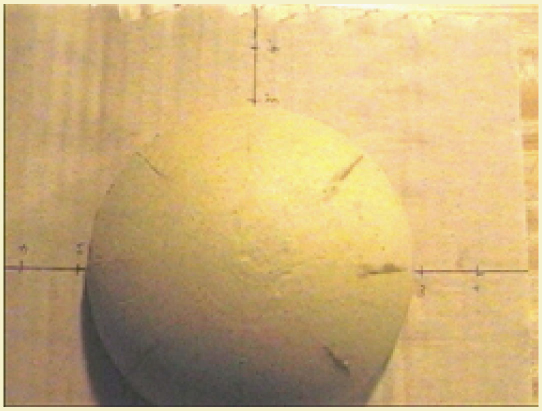

Figure 4: Using a guide to mark the ring quadrants.

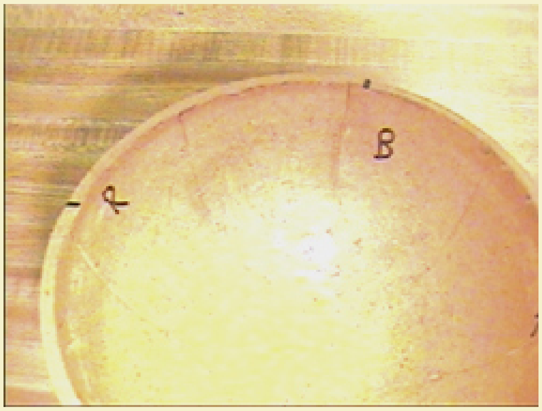

Figure 5: Ring colors are marked inside the hemi.

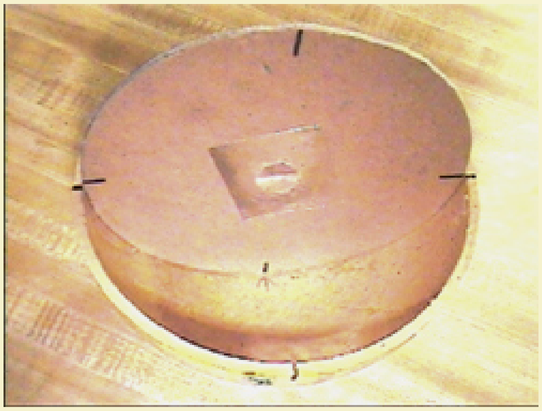

Figure 6: A disk is used to draw a guideline on the inside hemi wall.

and 90 degrees from each other. Place the hemi on a piece of cardboard that has two perpendicular lines drawn on it. These lines are marked at 1 inch intervals to make it easy to center the hemi on the "cross-hairs". (Figure 4). Mark on the hemi where the lines are, thereby separating the hemi into four quadrants. Next, put the two 6" hemis together and transfer the marks to the other hemi. Also, transfer the marks to the rims of the hemis and label inside the hemi what the ring colors will be (Figure 5). These marks layout the planes where two of the rings will go. The third ring will be placed along the rim of the hemi that has the time fuse in it.

Next, take a cardboard circle that has the same diameter as the inside of the hemi. Place it on the cardboard with "cross-hairs" and make four marks on it, splitting it into four equal quadrants. Insert the cardboard disk straight into the hemi such that the disk is at one of the sets of marks that split the hemi into quadrants. Two marks on the disk should be at the rim of the hemi. Make an arrow in the bottom of the hemi where the mark on the disk is (Figure 6). This is on the arc where one of the rings will be placed. Remove the cardboard disk and re-insert it at the two rim marks that are 90 degrees to the first set of rim marks. Line up the disk with the arrow that you just made inside the hemi and draw a line from one rim mark, through the arrow and up to the other rim mark. Also, make a second arrow mark on the hemi where the disk mark is. This will mark the arc for the second ring. Now, re-insert the disk at the first two rim marks, lining up the disk to the second arrow (Figure 7). Draw another line through this arrow outlining where the second ring of stars will go. This procedure will need to be repeated on the other hemi as well.

Next, on the outside of each hemi, mark where the rings are located and label what color star will be in each ring. You will need these markings when you put the two hemis together.

The Rings

There are various ways of inserting the rings of stars. One option is to use hot-melt to glue the stars to the hemi (See Kyle's article 6" Kaleidoscope w/Crossing Rings). This risks having a distorted ring in the sky if you use too much hot melt but, with care, it's easily done and works well.

Another option is to roll the stars in tissue paper and lay the tube of stars into the hemi. The main problem with this approach is that the rings will tend to look disjointed. This happens because the rings cannot be rolled in a single piece of tissue paper. Since the three rings will be intersecting each other, arcs would have to be rolled and then pieced into the shell to form a ring. When the shell breaks open and the stars move outward and away from each other, the tissue paper tends to hold the stars together just enough so that noticeable gaps are formed between the groups of stars in each arc.

A third alternative is to glue pieces of trimming or rope into place and use them as shelves to lay the stars on. For an 8" shell with 1/2" stars, I use braided trimming, obtainable at Wal-Mart or sewing centers. For this 6" shell that uses 3/8" stars, we can use 1/4" clothes line rope instead.

Take the rope and mark it at the following lengths: 7 1/4", 10 1/2", 13 3/4", 21 1/2", 25 1/4", 28 3/4". Wrap a piece of tape around the rope at the markings and then cut the rope. The tape will prevent the rope from unraveling. You should have pieces that are, in order, 7 1/4", two at 3 1/4", one at 7 3/4", one at 3 3/4" and one at 3 1/2". The pieces of rope are then hot-melted into the hemi, offset slightly from the ring lines. The rope needs to be far enough from the ring lines so when the stars are placed on the rope, they will be on the ring line. It may be helpful to lay the rope in place before gluing so that you'll know how they'll fit. If the pieces of rope have a lot of curl to them from being coiled, you can straighten them by soaking them in water and work the pieces until they are straight.

For the hemi that will have the time fuse, hot-melt in place the 7 1/4" piece first, making sure that the ends of the rope are down enough from the rim to allow a ring of stars to be placed above it. Then hot-melt in place the two 3 1/4" pieces for the other ring, again leaving space at the rim for the third ring (Figure 9). Using an awl or a drill, make a hole in the center of the hemi and insert the time fuse w/ extender. Leave about 1.5 cm of fuse poking through the hemi.

For the other hemi, hot-melt in place the 7 3/4" piece of rope first. This should be close to the rim of the hemi, but not over it. The 3 3/4" piece is hot-melted in leaving a gap between it and the long piece of rope so that the stars will fit between them. Then the last piece of rope, 3 1/2" long is glued in to finish the process.

If there is any excess hot-melt between the rope and the line where the stars will go, it will have to be trimmed away so that it doesn't interfere with the placing of the stars. When done, they should look like Figure 10.

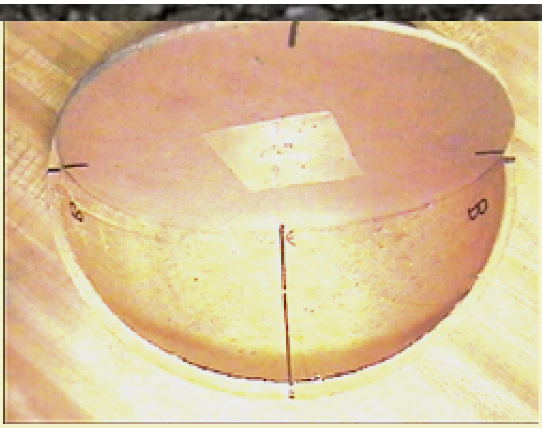
Figure 7: Marking the second, intersecting ring guideline.

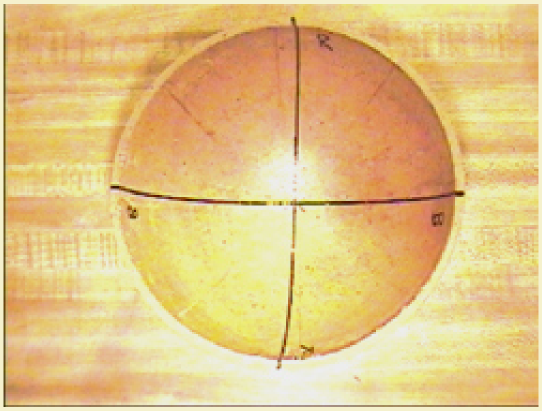
Figure 8: Hemi is marked, labeled and ready to load.

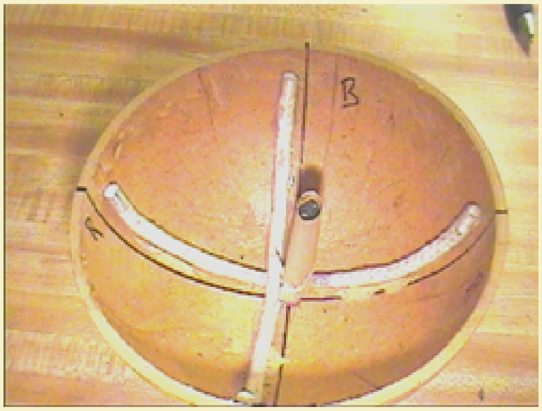

Figure 9: Segments of clothesline rope glued to the hemi as a guide for star placement.

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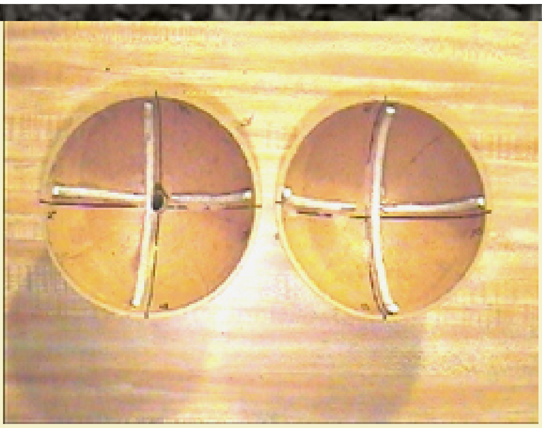

Figure 10: Both hemis prepared with the rope guides for two intersecting rings.

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6" Atomic Pattern Shell...

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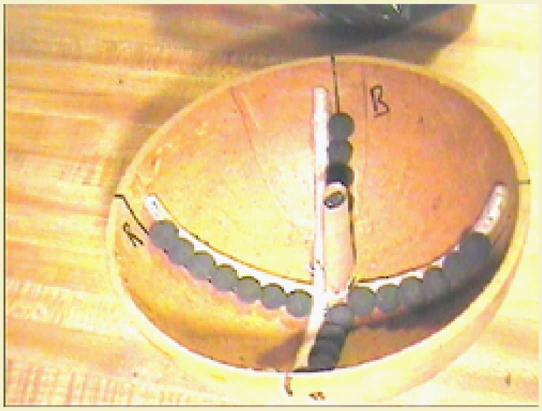

Figure 11: Placing stars along the rope guides.

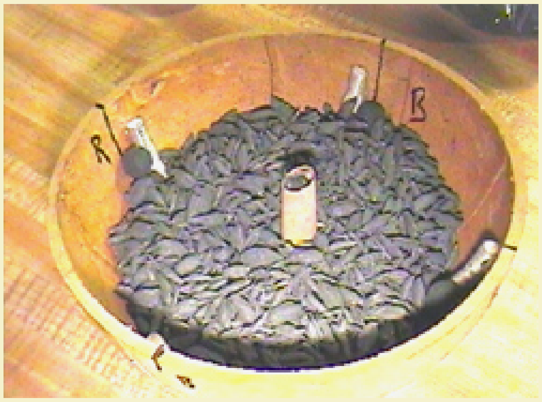

Figure 12: Partial burst charge loaded on top of ring stars.

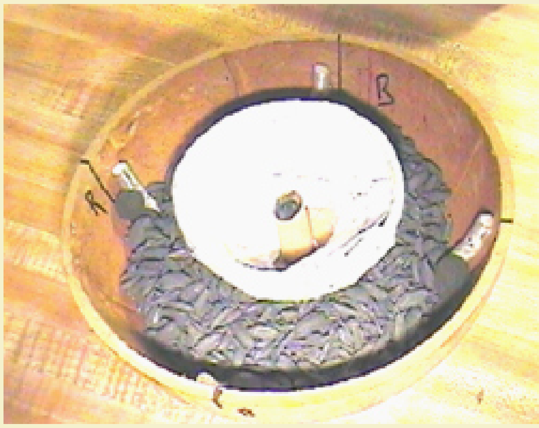

Figure 13: Inner petal cavity former is slipped over the time fuse.

Placing the Ring Stars

Next, the stars are placed on the rope. Slightly tilt the hemi on its stand such that when the stars are placed, they will stay on the rope. Place stars only up to 1/2" from the rim. Otherwise, these upper stars tend to roll down into the hemi. Also, in the fused hemi, you'll need to leave sufficient room along the top of the hemi for the final ring (Figure 11). Carefully place 1 cup of burst into the hemi (Figure 12). Center the 3" hemi with tissue paper into the burst, making sure that the rim of the 3" hemi is slightly above the rim of the 6" hemi (Figure 13).

Starting on the low side of the tilted hemi, carefully place the burst charge into the shell. When the burst is near the top, add the last stars to finish the rings. Work your way around the hemi, from the low side to the high side, adding burst and stars until it's filled. Level out the hemi on its stand and add burst to fill it. Since this is the fused hemi, add the stars to make the third ring by carefully pushing them into the burst. While pushing the stars in, roll them towards the hemi so that the burst underneath will be rolled out towards the inner hemi (i.e. the nucleus). Place a piece of cardboard over the hemi and lightly tap on the outside to settle the burst without knocking the stars out of alignment. When tapping, I try to avoid hitting where the rings of stars are located. Remove the cardboard. Add more burst and/or readjust the stars and 3" hemi if necessary. Replace the cardboard and settle the burst again. The hemi should now be filled to the rim (Figure 14).

Forming the Nucleus

While holding the 3" hemi in place, carefully unfold the excess tissue paper and spread the tissue out leaving the hemi clear (Figure 15). Now, the 3" hemi can be removed leaving the tissue paper in place (Figure 16).

Gently place the stars for the nucleus into the indentation left by the hemi, making sure that you don't disturb the burst under the tissue paper. If the stars don't exactly reach the rim of the indentation, it's better to leave them a little bit below the rim than to be too high. If you have properly settled the burst, there won't be much settling when you put the two hemis together. Once the stars are in place (Figure 17), add about ¼ cup of burst to the center. If you have many top stars that are well below the rim, you can raise them while adding the burst, letting some burst go under the top stars. This will help prevent a noticeable gap between the two halves of the nucleus when the shell breaks open (Figure 18).

Carefully gather up the excess tissue paper and fold it over the top of the nucleus. This will help keep the upper part of the nucleus round when you settle the burst. Once again, place the cardboard on top of the hemi and tap the outside to settle the burst. Remove the cardboard and cut back the excess tissue enough to make sure the fire can easily pass between the hemis. Fold what excess tissue remains, back over the nucleus (Figure 19).

Repeat this whole procedure for the other hemi, with the exception that the third ring won't have to be included. Just slightly overfill with burst before tapping and settling.

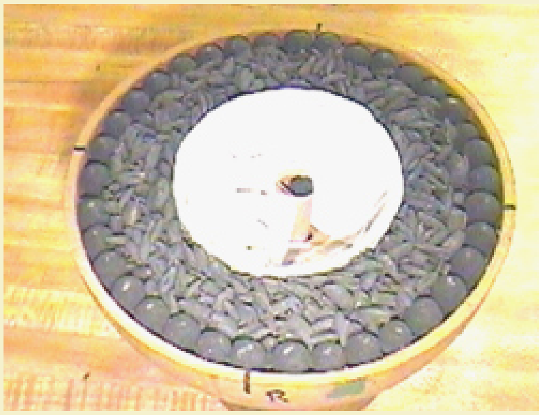

Figure 14: Burst charge and ring stars loaded in around the cavity former.

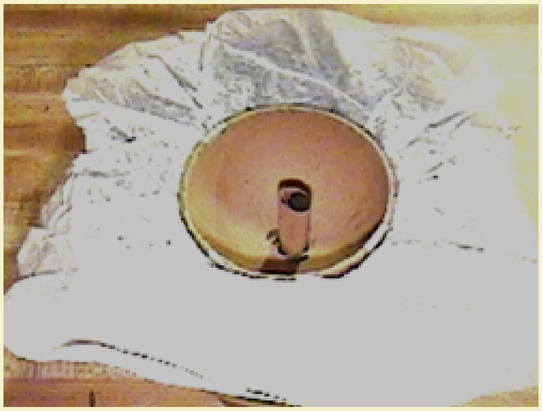

Figure 15: Tissue on cavity former is opened up to remove the former.

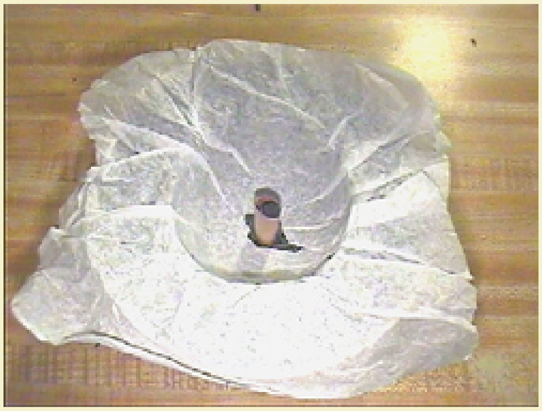

Figure 16: The former is removed and the cavity is ready for stars.

Putting the Shell Together

Take a 20" x 20" sheet of tissue paper and fold it in half twice so that it's now 10" x 10". Snip off the corner where the center of the tissue paper is so that there is a hole in the center of the paper. Now, crumple it up to make it pliable. Unfold the paper and wrap it over and around the 6" hemi that doesn't have the time fuse in it. Twist the ends together to make the tissue paper fit snugly without ripping it. You'll have to slightly tear the tissue paper near the rim to expose one of the ring marks so that you can properly align the two hemis (Figure 20).

With one hand holding the twisted tissue paper, place the other hand over the center of the hemi and flip it over. Carefully place the hemi over the fused hemi while aligning the marks, and slide out your hand. There should be only a very small gap between the two hemis. Tap them lightly to bring them together while making sure the ring marks remain aligned. Tear away the tissue paper, leaving it undisturbed inside the shell. I use 3/4" strapping tape at each of the pressed seams of the hemis to hold them together (Figure 21). Then I put one layer of masking tape around the seam where the two hemis came together. Check the time fuse to make sure that you still have at least 5/8" sticking out and hot-melt or glue it to seal the opening from gases. At the top of the shell, tape a piece of string that will be the hoop where your leader is slipped through.

Special Notes

The geometry of the burst charge filler is an important aspect to getting this shell to perform correctly. The standard flakey type of rice hulls commonly available will not work here. The large football shaped hulls seen here were obtained from Riceland Foods, and are similar to what are used in commercial rice hull break charges from China and elsewhere. If the correct type of rice hull can not be found, puffed rice cereal could probably also be substituted with similar performance. The hulls are coated in a ratio of 10.5 pounds of KP to 2.5 pounds of hulls, which is a 4.2 to 1 ratio. The KP charge used was 7 parts potassium perchlorate, 3 parts Service Chemical airfloat charcoal and .5 parts dextrin. The coating process should be done in a star roller or cement mixer so that all the powder is solidly coated onto the hulls, as opposed to the less reliable method of mixing wet hulls with dry powder by hand.

The shell can be pasted in with virgin kraft strips and wheat paste, or gum tapped with a minimum of three layers that overlap 50% (six effective layers). Note that pattern shells such as this often break slightly less hard than a peony or double petal shell of the same size. This is to keep the pattern stars from spreading out to far and thinning out the pattern. Too much distance between ring stars or any other type of 2D pattern will make the pattern more difficult to visually recognize.

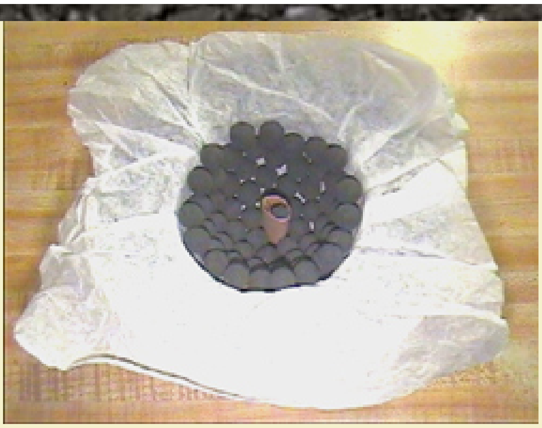

Figure 17: Loading stars into the 3" cavity to form the "nucleus" of the atom pattern.

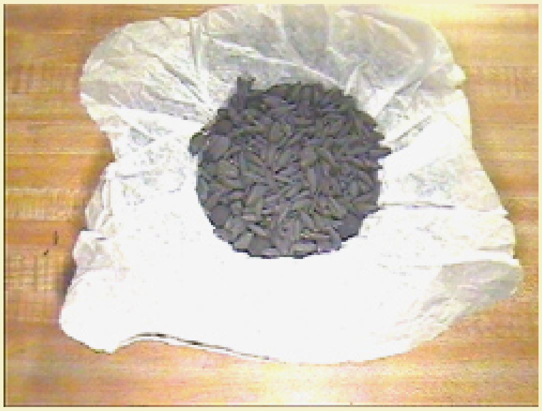

Figure 18: Remainder of space is filled with burst charge.

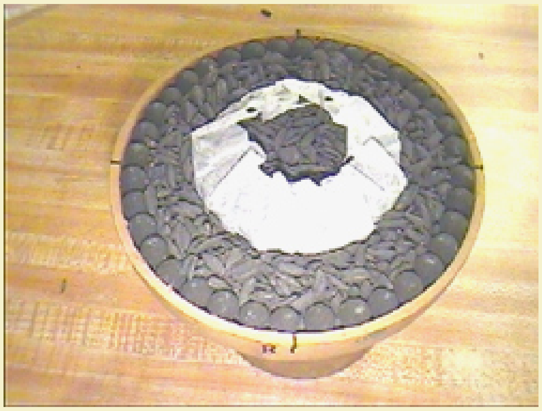

Figure 19: Tissue is trimmed and folded into the center.

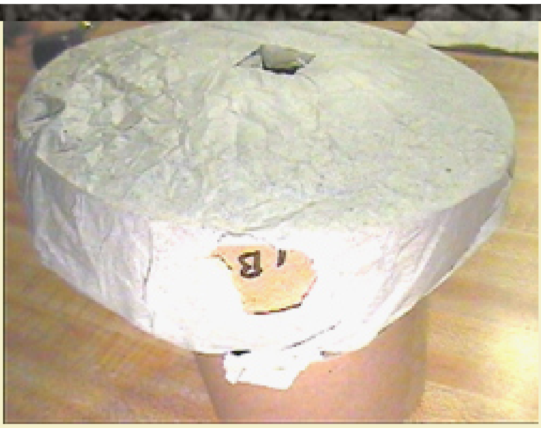

Figure 20: Piece of tissue placed over one shell half prior to inverting it onto the other half.

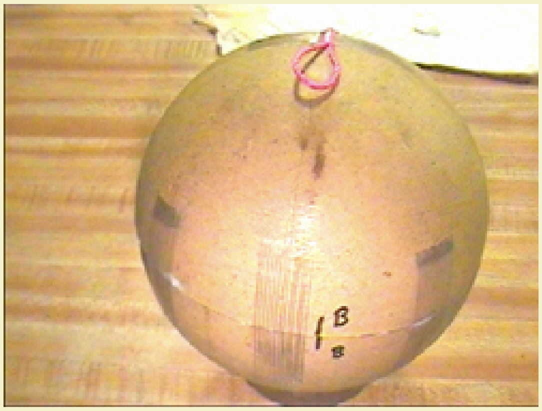

Figure 21: The shell seam is held together with pieces of fiber tape after closing the two halves together.

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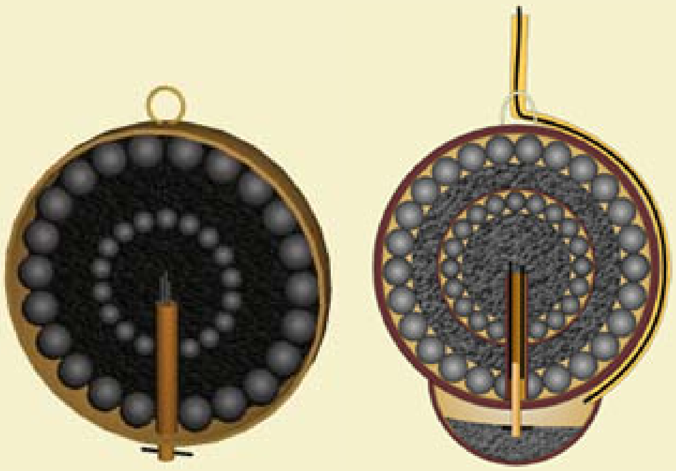
Volume 2, Issue 4

Build This...

6" Double Petal Ball Shell



April, 2002 Issue

Build This:
6" Double Petal Ball Shell

Technique:
Pasting Paper Ball Shells

Design Notes:
Strip Pasting Calculations

Autopsy:
Lidu 5" Crossette Canister Shell

Summary:

This classic round shell is the staple of many displays and gives the artist a wide variety of color combinations and effects. If done correctly, the effect is one round break nested inside of a larger round break. Common smaller inner petal stars include solid colors, streamers or even strobe stars. The larger outer petal stars should be designed to complement the inner effect so the two petals are visibly distinct.

Materials:

- (2) 5-3/8" OD hemispheres
- (2) 3-3/8" OD hemispheres (optional)
- (1) 2-1/2" long x 3/8" ID tube
- (1) 2" long piece of chinese time fuse
- 450 g KP rice hulls, 6:1

Tools:

- Hot glue gun
- 16" x 1" dia wooden dowel
- Scissors
- Cross match punch

Unmeasured Materials:

1/2 to 5/8" dia stars, 1/4 to 3/8" dia stars, cross match, tape, tissue paper

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6" Double Petal Ball Shell...

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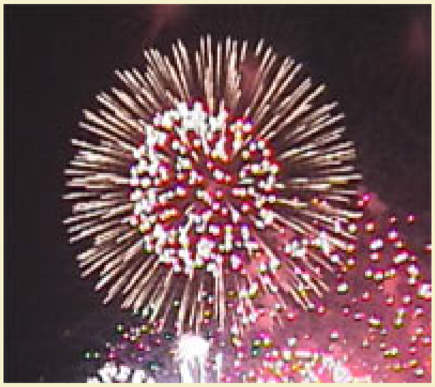
Figure 1: A commercial double petal opens during a finale.

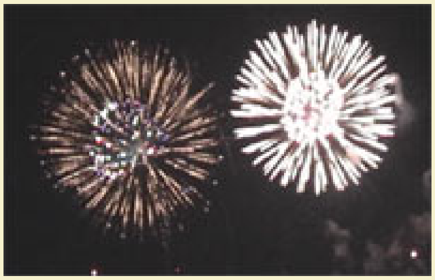
Figure 2: Distinctive inner petals visible inside outer petal.

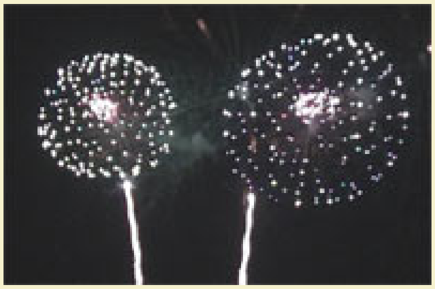
Figure 3: These shells have an inner pistil, which is not the same as an inner petal.

Introduction:
The double petalled round shell, be it a peony or chrysanthemum, is an attractive effect in which one sphere of stars is nested within a larger sphere. The inner sphere is typically one half the diameter of the outer sphere, and the effects of both petals should be designed so that the inner petal is clearly visible.

The Japanese refer to the stars that make up the inner petal as pistil stars, but this can be misleading since a shell with inner pistils is a different effect than one with inner petals. An inner pistil is simply a cluster of stars located at the center of the shell, and the effect looks like Figure 3. Inner petals, however, are arranged in a sphere just like the stars at the outer edges of a normal round shell. If done right, this will result in a spherical inner break instead of a random cluster.

The most difficult thing to master with this type of shell is getting the inner petal to appear perfectly round. From Figure 1 and 2 it can be seen that even commercial shells have difficulty with this. The inner petal stars must be positioned in a good sphere, centered in the shell, and kept that way until the shell breaks. If a container is not used to hold them in place, then they are subject to shift during the closing phase of shell construction, or even during the violent lift and burst events.

It would seem that the larger the shell is, the easier it is to make the inner petal break round. Figure 1 is probably an eight inch shell, where Figure 2 looks like six inch shells. The six inch size is about the smallest diameter I would use for attempting this effect. Going any smaller leaves too little room for the burst charge and doesn't allow much space for an inner petal.

Due to the extra space consumed by the inner petal stars and any case that may be used to hold them, there is less space available for burst charge in a double petal shell. Thus, the strength of the burst that is used must be higher than that used for a single petal shell of the same diameter. For the six inch paper shell described in this article, the burst charge is KP on rice hulls in a ratio of 6:1. The hulls were coated using a star roller as described here.

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6" Double Petal Ball Shell...

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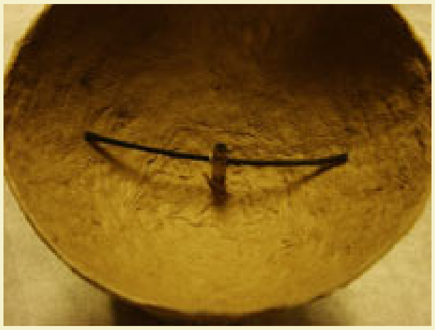

Figure 4: Cross matched time fuse inserted through bottom of hemisphere.

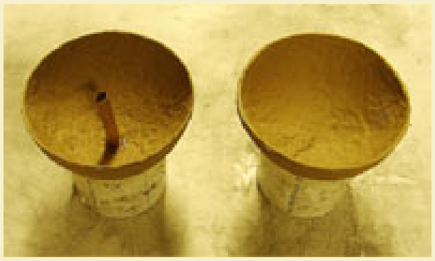

Figure 5: Center tube hot glued over time fuse.

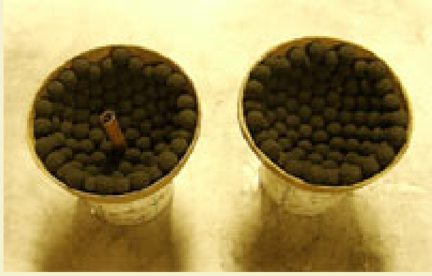

Figure 6: Stars loaded in place.

Construction:
Two hemispheres measuring 5-3/8" O.D. are required to hold the contents of the shell and provide a sturdy surface to paste over. The commercially available Chinese or Japanese paper hemispheres work well, with the Japanese type being the highest quality. Be aware that both types come in two different sizes for six inch shells.

The Chinese hemispheres come in a larger size for poka shells, which are too large to allow the necessary number of paste layers for this shell. The Japanese type are available in nested sets, with an inner set that fits snugly inside an outer set, thus reducing the number of paste layers required to finish the shell. Using the nested sets are a bit expensive, but should work with less time spent pasting. If you want to use the traditional method of pasting over a single set of hemispheres, make sure you order the inner size and not the outer size.

Plastic may also be used if they are pasted over at least six layers when closed. The type of hemispheres shown in the illustrations are made from recycled paper using the vacu-form method.

Prepare one hemi with a piece of time fuse measuring 1-1/2" between cross match holes (assumes a burn rate of 2.2 seconds per inch). The end of the time fuse that goes inside the shell should be cross matched with a 5" long piece of match before inserting the time fuse. A bead of hot glue is run around the time fuse joint both inside and outside the case. A 2-1/2" pipette made from a few turns of 70lb kraft is placed over the time fuse and cross match inside the shell, held into place by the bead of hot glue around the base of the time fuse. Extra sticks of black match may also be inserted into the pipette to help increase the jet of ignition fire.

The two hemispheres are next loaded with the outer petal stars until filled just below the rim, as seen in Figure 6. Occasionally jostling the shell helps the stars settle into place and fill the gaps.

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6" Double Petal Ball Shell...

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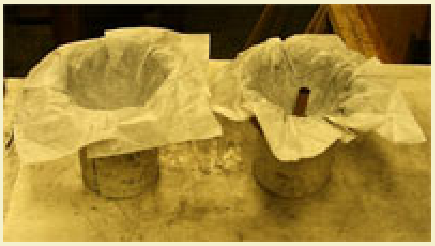

Figure 7: Tissue paper liner placed over stars.

After the stars are loaded a tissue paper liner is placed over them, which helps prevent the stars from migrating into the burst charge during assembly and transportation. It may help to form the tissue over a 5" hemisphere prior to placing it in the shell so that it will lay down better. Using scissors to make four cuts around the edges of the tissue paper half way to the center also helps the paper lay down easier.

The hemispheres shown in Figure 8 are used to hold the inner petal stars in place. These were made using the vacu-form method, but another type can also be made by pasting half circles around a former and drying them out. Holes are punched in the paper in order to help transfer fire from the inner petal to the outer petal. The vacu-form hemispheres are very weak and easy to punch with an awl or screwdriver. In fact, these hemispheres are so easily torn during burst that the shell will still function properly with no holes at all, but it doesn't take but a minute to perforate them.

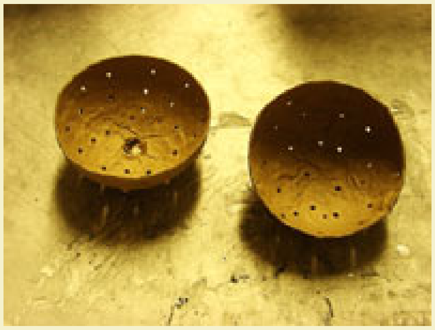

Figure 8: Inner hemispheres punched with holes to help fire transfer.

Plastic hemispheres can also be used, but the fire transfer holes must be drilled instead of punched, so they take slightly longer to prepare. The same is true of commercial paper hemispheres, although these are a bit thicker, more expensive and consume more space in the shell. Thin paper hemispheres are ideal.

Another method of creating the inner petal does not require hemispheres. The tissue is filled 2/3 full with burst, then a paper or plastic hemisphere is pushed into the burst charge and removed so that a spherical indentation is formed. The stars are then carefully placed into this cavity. However, I believe the use of rigid hemispheres results in a rounder inner petal that is not susceptible to becoming deformed as the shell is closed.

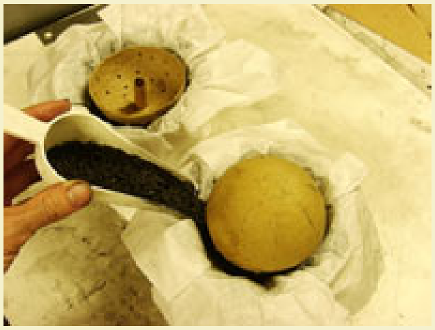

Figure 9: Pouring break charge around inner hemis.

With the tissue in place, a handful of burst charge is placed into the bottom of each half. The inner petal hemispheres are now placed on top of this bedding of burst charge, rocking them into place so that the rim of the inner hemi is even with the rim of the outer hemi. The remaining space around the sides of the hemi is then filled with burst charge. Figure 9 shows how a paper hemi placed over the inner hemi can be used to prevent burst from falling inside when pouring around the outside.

After both inner hemispheres are shimmed into place with burst charge, they may then be filled with the smaller 1/4" or 3/8" stars as shown in Figure 10.

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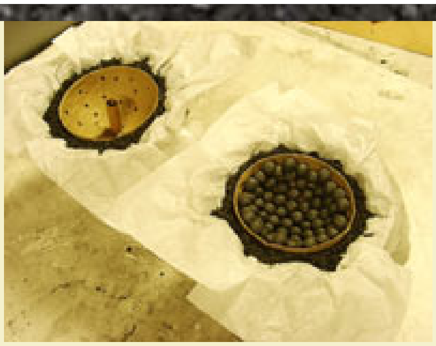

Figure 10: Loading inner petal stars.

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6" Double Petal Ball Shell...

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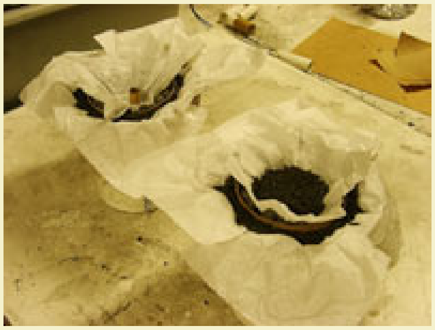

Figure 11: Tissue paper liner placed over inner petal stars and filled with burst charge.

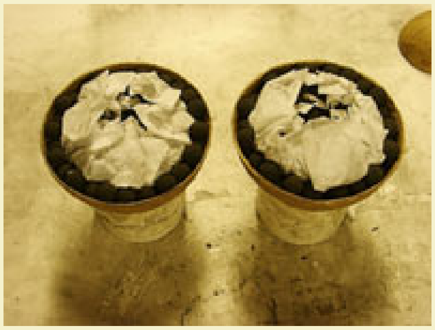

Figure 12: Tissue paper liners are trimmed and gathered up.

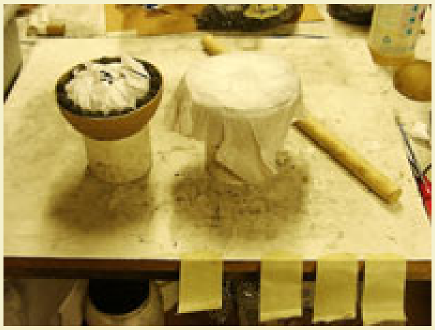

Figure 13: Sheet of tissue used to hold in contents when right hemi is inverted onto left hemi.

After loading the inner petal stars into both hemispheres, another tissue paper liner is added as before. The remainder of the space inside the liner is filled with burst charge until level with the edge of the casing.

The excess tissue paper is now trimmed with scissors and folded in as shown in Figure 12. The stars for both petals are inspected for gaps, and additional stars are wedged in place where needed. There will be some stars that stick up above the casing and other spots where the stars don't quite make it to the edge of the casing. Judging the placement of stars is somewhat of an art, since too many will prevent the shell from closing and too few will result in a visible "seam" when the shell breaks.

Position the two shell halves next to each other and try to align them so that stars sticking up above the hemi wall will be matched with stars that rest below top of the hemi when one half is flipped over onto the other. The stars will shift during the closing process, but it is good to try and get things to interlock as best as possible going into the process.

Extra burst charge is added around the top of the inner petal and wherever else needed to bring everything level. Since rice hull burst is slightly compressible, a slight excess of burst may be mounded up in the center of the shell. The purpose of this is to provide a solidly packed shell when it is forced closed.

Closing the shell is done by flipping one half of the shell over onto the half that contains the time fuse. In order to keep the contents from spilling out during this process, a sheet of tissue paper is placed over the half to be flipped as shown in Figure 13. This sheet is carefully held in place with both hands while turning the hemi over as shown in Figure 14.

There should be a gap of about 1/4" between the two halves when they are put together. This gap must be closed by lightly rapping the sides of the shell with a wooden dowel rod while pushing down on the shell from above. The rod is tapped above and below the seam for the entire circumference of the shell until the gap is closed. This action causes the stars to shift and fall into place. On occasion you may overfill the shell and not be able to close the gap. If this happens, you must grasp the tissue paper and remove the top half, making sure that nothing spills. The contents are adjusted by removing break charge and stars where necessary, then reassembled as before.

If there is no gap when the halves are put together, then you probably under filled the shell. This will result in a shell that is not packed as tightly as it should be and can allow stars to shift and migrate out of alignment. An under-filled shell can also result in less structural integrity, although it is not likely that a shell of this size would get damaged on lift if properly pasted in.

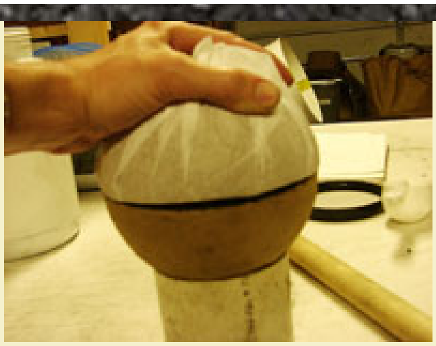
Figure 14: Closing the gap by tapping with wooden stick.

Once the gap is closed, the tissue paper is torn away and the halves are held together with pieces of masking tape running around the circumference of the seam. A small flag of tape is placed around the time fuse to protect it during pasting.

The shell is now loaded and ready for pasting. Several methods of pasting are described in this month's pasting article. To determine how many paste layers are required for the type of paper you are using, check out the guidelines given in the paste layer calculation article.

Related Articles:

Pasting Methods for Ball Shells
Paste Layer Calculations for Ball Shells
Round Stars, Part I
Round Stars, Part II
6" Ring and Bow Tie Shell

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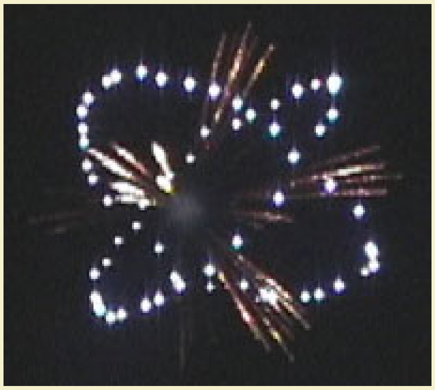
Build This...

Kaleidoscope w/Crossing Rings



Summary:

This unique combination of ball shell patterns makes for an attractive display when the right color combinations are chosen. The branching arms of the kaleidoscope effect, when done with a subtle streamer type star, contrasts nicely with a bright set of color rings.

This article shows both the techniques for making crossing rings as well as a few different methods for making kaleidoscope patterns (sometimes called octopus pattern).

Materials:

- (2) 6" paper hemispheres
- (1) 2.5" long 3/8" I.D pipette
- (1) 2" long time fuse
- (36) 36" long x 3/4" wide 70lb kraft strips
- (1) 5" piece of cross match
- 1/2" color stars
- 1/2" streamer stars
- BP on puffed rice cereal

Tools:

- Hot glue gun
- 1" wooden dowel rod
- Two 4" pvc couplings
- Drafting compass
- Drafting square
- Felt tip marker

Unmeasured Materials:

2" masking tape, hot glue, wheat paste

February, 2003 Issue

Letter from the Editor:
They're Talking About Us!

Build This:
Kaleidoscope w/Crossing Rings

Technique:
Attaching Large Comets to Shells

Tool Tip:
Build A Drying Box

Autopsy:
8" Saturn Shell

Class C Corner:
Scuba Diver, Land of the Free

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Kaleidoscope w/Crossing Rings

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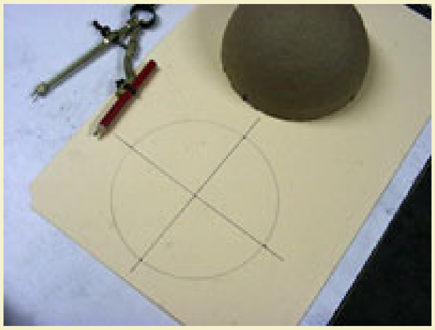

Figure 1: Drawing out the ring placement guide.

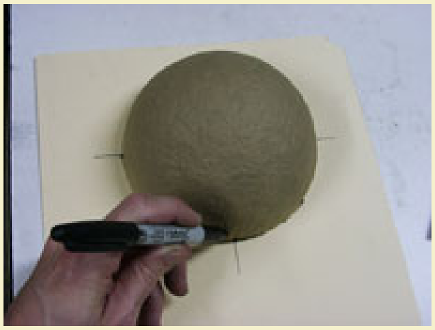

Figure 2: Marking each hemisphere for ring star alignment.

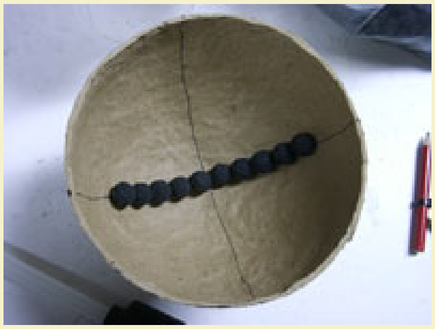

Figure 3: Hot gluing ring stars into hemispheres.

Loading the Rings:

There are a few different ways to make a crossing ring shell. One way is to install a half ring in each hemisphere, load the break charge into the hemispheres and then create the second ring around the rim of one the hemispheres. The second way is to create two intersecting half rings in each hemisphere so that they form two rings when the shell is closed.

I have chosen the latter method for this shell, mainly because the half rings divide each hemisphere into four quadrants, which makes it easier to place the kaleidoscope stars in the correct positions. It also allows all stars to be locked in place prior to loading the burst, which is more efficient if you were making many of these shells assembly line style.

The first trick is to insure that the two rings align properly when the shell is closed, since any offset will cause a break in both ring patterns. A marking guide is first made as shown in Figure 1, which allows four equally spaced points to be marked onto the outside of the hemispheres.

Use the marking template to mark one hemisphere, then put the two hemispheres together and transfer the points to the other one as well. One set of marks should be distinct so that the shell can be closed in the exact same position that it was in when the marks were made.

The 2" time fuse should be cross matched at 1/4" from each end and fused with a 4" long piece of black match. Insert the time fuse through a 7/32" hole in the bottom of one hemi so that at least 1" protrudes on the outside. Hot glue around the inside base of the fuse, fold the black match up into the center of the shell and insert a 2-1/2" long pipette down over it so that it sinks into the hot glue at the base. I like to cram in extra pieces of black match into this pipe to insure a good fire transfer into the center of the shell. When the glue on the inside base of the fuse has dried, apply a bead of hot glue around the fuse base on the outside as well.

Next take your pen and try to draw guidelines between the marks where the rings will be. This makes it much easier to keep the stars straight when gluing them in. Using only a dab of hot glue per star, attach the ring stars as seen in Figure 3. Figure 4 shows both sets of rings fully completed.

More...

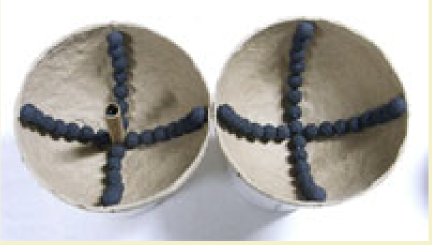

Figure 4: Crossing ring stars glued in place.

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Kaleidoscope w/Crossing Rings

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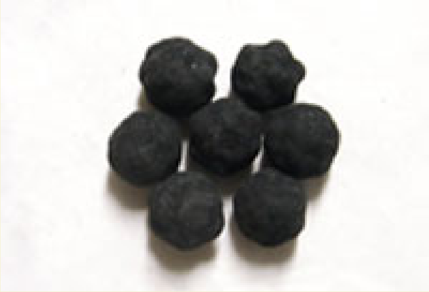

Figure 5: Gold streamer star cluster to be wrapped in tissue.

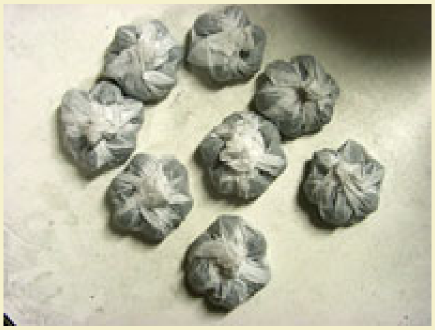

Figure 6: Eight star bags for the kaleidescope effect.

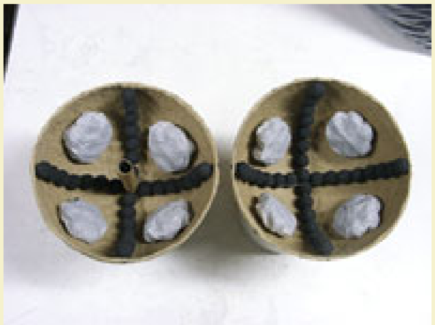

Figure 7: Star bags hot glued in place.

The Kaleidoscope Stars:

Kaleidoscope is the name given to the effect created when tight clusters of stars shoot from a shell break with a lot of space around them. This creates the effect of long spikes, often in symmetrical groups of eight. The kaleidoscope effect, sometimes called an octopus shell, is most effective when the stars leave long streamers behind, or streamer to color combinations. Using four opposing sets of color is also an attractive effect.

This effect is achieved by placing small groupings of stars equally spaced at each quadrant of the shell. The method I prefer to use involves wrapping a group of stars in tissue paper and gluing these star bags to the shell wall. Figure 5 shows seven 1/2" streamer stars ready to be wrapped. A single layer of tissue is wrapped around the stars, twisted at the top and the excess tissue cut away. Figure 6 shows the eight star bags required for this shell.

Hot glue is applied where the tissue twists together, then each bag is centered between the rings stars as seen in Figure 7.

An alternate method of creating the kaleidoscope effect is to use small perforated hemispheres to encapsulate the star clusters. Imagine a tiny wiffle ball cut in half, filled with stars, then glued into the positions shown in Figure 7. This method seems like too much work to me, but it is used in some commercial Chinese shells.

The last trick is the use of my favorite break charge- BP on puffed rice cereal (4:1 ratio BP to cereal). This charge works well on all pattern shells where there is a large volume for the burst charge to fill. This same charge will also break a single petal 8" ball shell quite well. The grain size, shape and resistance to compression obtained with puffed rice cereal is very close to the break characteristics of the rice hulls used by the Chinese. American style rice hulls are more like flat flakes that do not fill large volumes well without creating fire blocks. These shredded type hulls also compress too easily for some applications.

Since the 4:1 BP/cereal charge doesn't compress much, be sure to level off the shells prior to closing. Figure 8 shows the shell ready to be closed. A sheet of tissue is placed over one hemi, which is then turned over onto the other one. Be sure to align the two key marks before closing the shell, otherwise the ring will be misaligned.

Use a dowel rod or similar stick to tap the shell together and settle the contents while you close the gap. Some 2" wide masking tape is then used to tape around the seam and hold the shell together. Be sure to tape the tip of the time fuse as well to protect the end during pasting.

This shell requires 6 layers of 70lb paper to paste it in, along with about 3

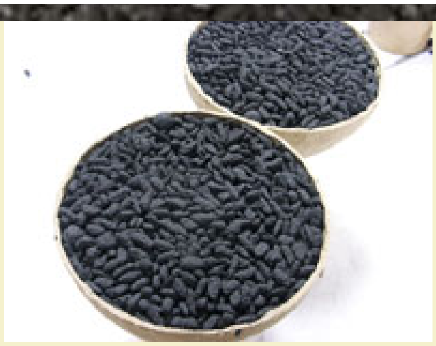

Figure 8: BP on puffed rice cereal break charge.

cups of wheat paste. You will need 36 strips of 3/4" paper that are 36" long to complete the paste job. This paper is prepared and pasted as shown here. The "assembly line" method mentioned on that page works equally well for just a single shell, and is the fastest way I know of to paste in a ball shell. Note that all six layers can be applied at once without drying between layers if the shell is dried using a drying box similar to the one shown here. Without forced drying I would recommend applying only two or three paste layers between drying in order to have your shell ready to shoot sooner.

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Build This...

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6" Ring and Bow Tie Shell

Introduction:
The Ring and Bow Tie shell is a common round shell pattern that combines a bow tie pattern at right angles to a center ring. The bow tie stars typically have long tails so that the bow tie pattern, also called a butterfly pattern by some builders, remains visible as the ring expands.

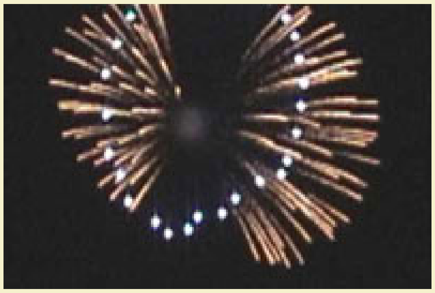

Figure 1: Shell built as described here.

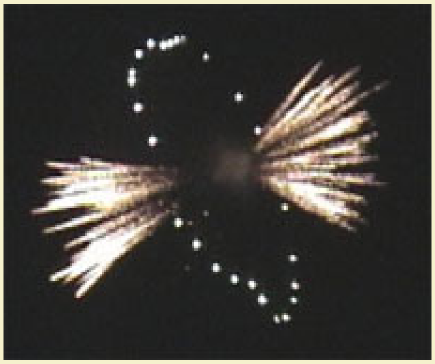

Figure 2: Bow tie using a narrower cluster of stars .

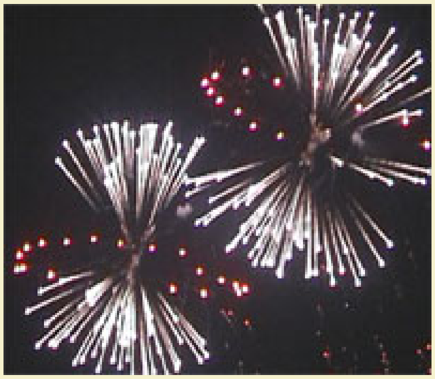

Figure 3: Commercial ring & bow tie shells.

Figures 1-3 depict different ring and bow tie shells in action. Figure 1 was built exactly as described here, while Figure 2 is a variation that uses a line of stars rolled in tissue paper to form the ring, as well as a rather disorderly clump of stars at the end of each hemi for the narrower bow tie effect. Figure 3 shows two commercial shells, one in which some of the bow tie stars were accidentally used in the ring pattern (upper right break).

The ring and bow tie shell presents two problems for the builder to overcome, making the effect more difficult to achieve than a typical color break. Like all ring shells, there is the difficulty in producing a perfectly round ring that stays flat within a single plane. The stars should also be evenly spaced in the ring. The small defects found in the rings displayed to the right, including the commercial shells, shows how difficult this is to achieve even after much refinement.

The second problem is breaking the shell such that all the bow tie stars take fire. This second problem arises due to the amount of empty space that the burst charge has to fill in the shell. The sparse number of stars used in this type of shell results in a large volume of burst charge, which makes it easy to over break the shell if the charge is not dialed in correctly.

If a typical KP on rice hulls burst charge is used to break this shell, not only will an unnecessary quantity of burst charge be used, but the bow tie stars will be blown blind. This is because such a large quantity of burst takes fire that the shell will rupture before the flame front ever reaches the edges of the shell where the bow tie stars reside.

The ring will often take fire however, since there is an unobstructed path for the flame to travel along the tissue paper seam where the shell halves are joined.

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6" Ring and Bow Tie Shell...

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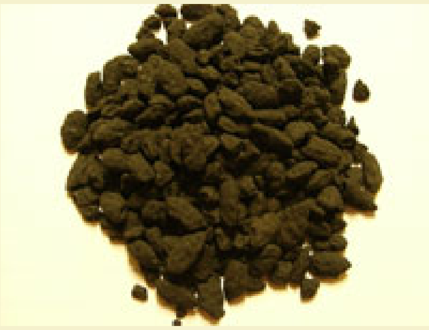

Figure 4: Closeup of BP on puffed rice burst charge.

Burst Charge Requirements:
The correct burst charge is the main key to getting this type of shell to perform correctly. The burst charge should have the following characteristics:

- Fast burning but not too strong
- High volume to weight ratio
- Does not compress easily, similar to pulverone
- Allows room between grains for gas and flame to travel

Black powder, having a relatively fast burn rate with lower gas production than other common break charges, is the logical choice here. While some pattern shells use commercial BP diluted with a hard filler such as meal coated beans, this results in an expensive and overly heavy shell. Using ball milled meal over some type of light core is the ideal solution.

Rice hulls do not provide the kind of bulk required to reduce the surface area of the burst charge while still filling a large volume. The amount of BP required to break the shell is only about 300 grams. If this amount were distributed onto the volume of rice hulls required to fill the shell, the ratio of powder to hulls would be very low, which would also hinder the speed of flame propagation.

Densely packed rice hulls also slow the flame propagation due to how close together the hulls pack, reducing the gaps for hot gasses and flame to travel through in their path to the stars waiting at the shell wall. One way to think about this is to imagine trying to pour water through a strainer filled with leaves. The leaves will lay flat against each other, and the weight of the water will force them together and block the passage of water through the leaves. A strainer full of gravel, however, will not be effected by the pressure of the water, which will easily flow around the gaps between the pieces of gravel. It is because of this effect that a hard, granular type burst charge is more desirable than a flat, compressible material like rice hulls. Rice hulls are fine for shells that are filled with one or more petals of stars, but the high volume of hulls used in the shell described here results in the "leave" problem and most if not all of the bow tie stars will not take fire.

Examining the burst charge removed from a commercial ring and bow tie shell autopsy, it can be seen that the grain size is very large. The core in this case was some sort of rice grain, while the coating was BP. The coating was very thick, resulting in both a large grain as well as a resistance to compression.

The final burst charge arrived at after some experimentation was a coating of BP on either popped popcorn or puffed rice in a ratio of about 4:1. Puffed rice is the preferred core, as it is cheap and can be used as-is. Popcorn must be popped, then forced through a 1/4" screen to knock the particle size down. Both cores are coated using a star roller as described here. The water causes both core types to shrink slightly upon drying, resulting in a lightweight charge, large grain size and very little compression when pressure is applied.

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6" Ring and Bow Tie Shell...

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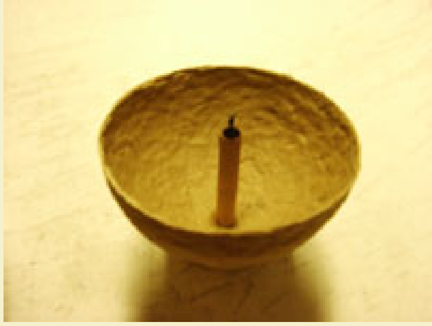

Figure 5: Hemi with time fuse installed.

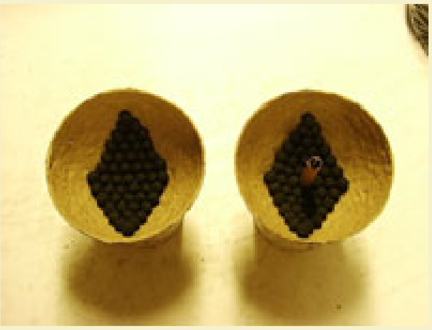

Figure 6: Bow tie stars arranged in diamond patterns.

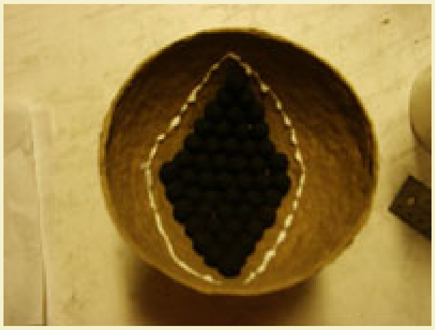

Figure 7: Bead of white glue around bow tie stars.

Loading the Shell:

The type of hemispheres used in this project are made from recycled paper using the vacu-form system. The hot-glue method of securing the ring stars has not been tested with other hemi types at the time of this writing, but it should work with them all. If the bond between the star and the hemi wall is too strong, then there may be a problem with the ring stars breaking out in clusters, which will affect the spacing between stars. Recycled hemispheres are ideal because the hot glue is easily stripped from the flakey, low density paper walls.

Prepare one hemi with a piece of time fuse measuring 1-1/2" between cross match holes (assumes a burn rate of 2.2 seconds per inch). The end of the time fuse that goes inside the shell should be cross matched with a 5" long piece of match before inserting the time fuse. A bead of hot glue is run around the time fuse joint both inside and outside the case. A 2-1/2" pipette made from a few turns of 70lb kraft is placed over the time fuse and cross match inside the shell, held into place by the bead of hot glue around the base of the time fuse. Extra sticks of black match may also be inserted into the pipette to help increase the jet of ignition fire that sprays out the tube when the cross match lights. The resulting assembly should look like Figure 5.

The two hemispheres are next loaded with the bow tie stars, which are usually 1/2" diameter streamer stars of gold, silver or glitter. These are placed in a diamond pattern as shown in Figure 6, with the middle row being seven stars across. The length of the diamond from tip to tip determines the spread of the bow tie pattern.

The bow tie stars must be held in place to prevent them from shifting around or migrating into the burst charge. Some manufacturers will spray the diamond pattern with a type of binder that glues the stars to each other and the shell wall. A mixture of NC lacquer has been tried for this purpose, which works reasonably well but adds a drying step and creates a potential ignition problem. It is just as easy to hold stars in place with a sheet of tissue paper and glued closely around the perimeter of the star pattern. Two sheets measuring 6-1/2" by 4-1/2" are cut from thin tissue and glued into place as shown in Figures 7 and 8.

Before loading the burst charge, make a mark on the outside of both hemispheres so that the diamond patterns will be oriented in the same direction when the shell is assembled. It is not necessary to wait for the glue around the tissue paper to dry before finishing the shell. The remaining space in both hemispheres is now filled with a burst charge of 4:1 BP on puffed rice. The side with no time fuse is filled all the way to the rim, while the other hemi is filled about 1/2" short of the rim. This will allow room for the ring stars to be glued in place before filling the remainder of the shell with burst charge.

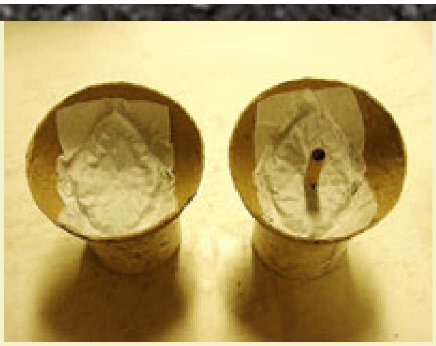

Figure 8: Tissue paper glued into place.

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6" Ring and Bow Tie Shell...

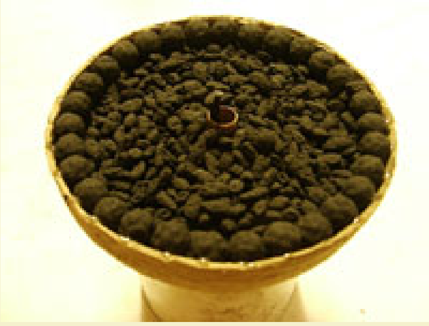
Figure 9: Burst charge and ring stars in place.

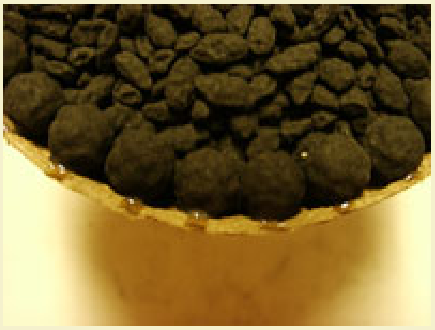
Figure 10: Ring stars held in place with dab of hot glue.

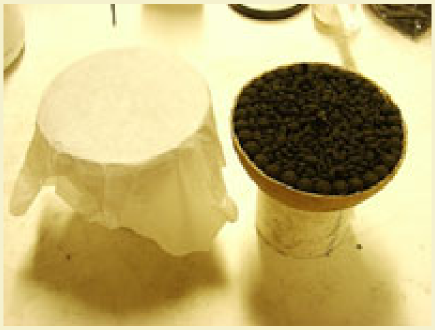
Figure 11: Shell ready to be closed.

Making the Ring:

The key to getting good ring patterns out of a shell is to insure that all the stars are properly positioned at the time the shell walls rupture. Once the stars are set in motion, they are simply an expanding image of how the stars were arranged at the moment the shell broke. Small deviances in position or misalignments in height are magnified several hundred times as the ring expands from a five inch diameter to a hundred feet in diameter.

Several things can cause a ring to be defective, even when the stars are loaded in what seems to be a perfect ring. Loose stars can migrate into the break charge toward the center of the shell. Loosely packed burst charge can allow the ring stars to shift out of their plane of alignment during the vibrations caused when closing the shell. If there is nothing to hold the ring pattern in its shape, the stars may even move during the violent forces that occur at the split instant before the shell breaks.

As already discussed, using a solid, uncompressible burst charge helps sandwich the pattern between two planes of solid support. In order to keep the stars from moving during the burst reaction, it is necessary to make sure they are supported by the walls of the shell so that they have nowhere to go until the casing breaks. The easiest way to insure their position is to hot glue them directly to the shell wall.

Begin by setting all the stars in position, then pull them away from the wall one at a time and place a drop of hot glue on the shell wall. The star is then pressed back into the glue to secure its position. Figure 10 shows a closeup of the drops of glue behind each star.

Once all the stars are glued in place, the remainder of the space is filled with the burst charge until level with the stars. The burst charge may be slightly heaped above the level of the shell walls at the center, but keep in mind that this type of burst charge will compress very little.

Closing the Shell:

Cut a square of tissue and place it over the hemisphere that does not contain the ring, as shown in Figure 11. Make sure the marks you made for alignment of the bow tie pattern are facing each other before putting the halves together. The tissue paper is held tight against the hemi as it is inverted and placed on the ring hemi as shown in Figure 12. If the gap between the two halves is 1/4" or more, remove the hemi and extract some of the burst from one or both halves. Once the gap seems closeable, use a wooden stick to rap the sides until both hemis come together.

Once the gap is closed, the excess tissue is ripped away and the shell halves are held together by strips of masking tape. If you are using the recycled

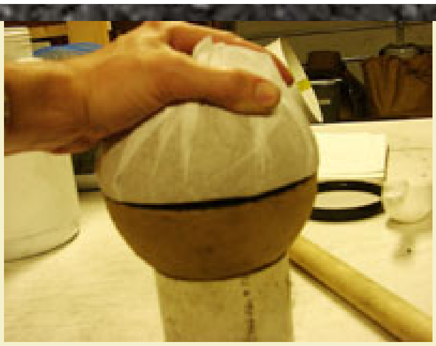

Figure 12: Closing the gap.

hemispheres shown here, you can protect them from absorbing moisture during pasting by covering the entire shell with masking tape at this point. This step is not necessary with commercial paper hemis or recycled hemis that have been protected using paint or varnish.

The shell is now pasted in the standard way for a six inch shell, using about 12 layers of 60-70lb paper to achieve a 1/8" thick wall.

Due to the very light weight of this shell, the ounce per pound rule can not be used to calculate the lift charge. At least 2.5 ounces of 2FA is recommended.

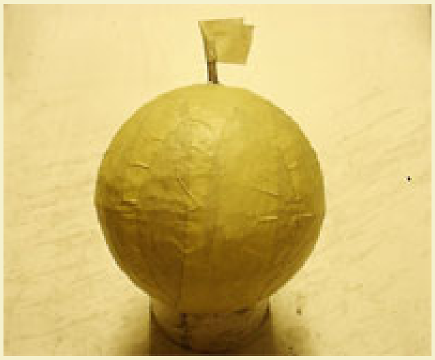

Figure 13: Ready for pasting.

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Build This...

8" Brocade Crysanthemum

Slow Gold formula shown here.

Summary:
An 8" ball shell is really no more work to build than a 6" ball shell, as they both take about the same amount of time to paste in. The break charge can be a cheap and easy to produce coating of black powder over cotton seeds. So roll up your sleeves and make that crowd pleaser you have been thinking about!

This article shows the assembly of an 8" single petal ball shell and the trick to coating cotton seeds with meal powder.

April, 2003 Issue

Where's the May Issue?

Build This:
8" Brocade Crysanthemum

Gallery:
Lily Fireworks Factory, Malta

Technique:
Casting Ball Mill Media

Tool Tip:
Making Ball Mill Jars

Autopsy:
4" Falling Leaves Shell

Prerequisite: 6" Ball Shell

Formulas: Blonde Streamer or Lancaster Yellow Glitter or Slow Gold or Fe/Ti Gold

Materials:

- (2) 7" I.D. hemispheres
- (38) 2" wide x 36" long 70lb virgin kraft strips
- (1) 1/4" Chinese time fuse, 2" between centers
- (1) 3/8" I.D. x 3.5" long thin wall pipe
- (3) 12" square sheets of tissue paper
- (1) plastic sandwich bag
- 3 cups wheat paste
- 120g 2FA lift charge
- 4.5 foot long quickmatch leader

Tools:

- hot glue gun
- cross match punch
- Plastic bucket

Unmeasured Materials:
cotton seeds, meal powder, 3/4" stars, cross match, 2" wide masking tape, foil tape, string

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8" Brocade Crysanthemum Shell

Page 2

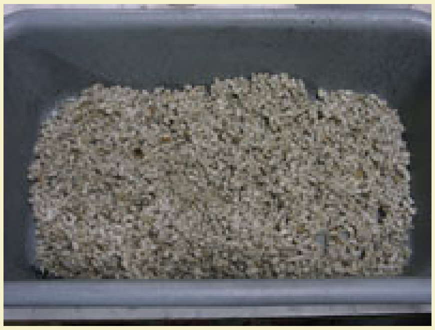

Figure 1: Cotton seeds in a mixing bucket.

Introduction:
As spherical shells increase in size, the internal volume to be filled with burst charge increases by a power of three. However, the amount of powder required to break these larger shells does not increase by a factor of three, thus a way is needed to reduce the amount of actual burst charge while still filling a large volume. This is commonly done by the use of "filler," which is any material that is coated with the burst charge in order to increase its volume without increasing the actual amount of burst charge.

The larger a shell gets, the larger the filler needs to be. While rice hulls work for smaller shells, something with more volume is desireable for bigger shells. This can be seeds, pieces of cork, beans, popped pop corn or any similar sized light weight material that powder can be made to stick to.

For this single petal 8" shell, either cotton seeds or puffed rice cereal are coated with ball milled meal powder to make the burst charge.

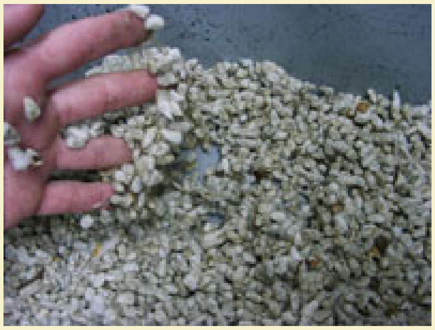

Figure 2: Cotton seeds dampened with water, but not soaked.

Cotton Seed Break Charge:
Cotton seeds make an ideal choice for burst charge filler for larger shells. They are a good size, cheap, light weight and they have a fuzzy coating that easily picks up the meal powder. The only drawback is they are not exactly easy to come by. There are no suppliers that sell them in hobbyist quantities that I know of, which means you have to be resourceful in finding them. This means you have to get on the internet and search for farming companies that sell cotton seeds, then convince one of them to sell or give you a "sample."

While cotton seeds sell at a very low price per pound, the companies that sell them have minimum container sizes that are prohibitively large for the hobbyist. Even a small scale supplier wishing to resell cotton seeds would have a difficult time storing a 40 foot trailer full of cotton seeds, which is a typical minimum order size.

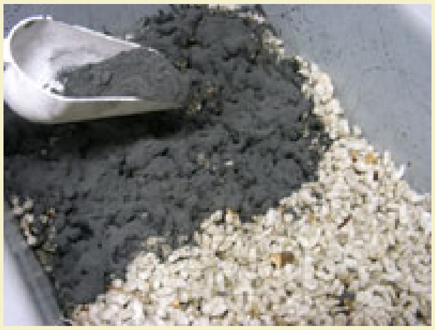

Figure 3: Adding meal powder to the damp seeds.

Obtaining a sample from a supplier may get you 100 pounds of cotton seeds at no cost at all. Cotton seeds can actually go bad in storage by sprouting, which is caused when the seeds have too much moisture. It is important to find out how long the seeds have been stored before getting any large quantity. If your supplier has had them around for a year or more, then you don't have to worry about sprouting. Otherwise you will have to dry your seeds in an oven to remove any moisture.

Coating Cotton Seeds:
There are a few methods I have heard of for coating cotton seeds. One method involves making a meal slurry and then pouring it onto the cotton seeds and stirring it around. Some builders report that this method can result in a big glob of entangled seeds if you are not careful. A similar method with similar complaints involves adding the dry cotton seeds into a tub of meal

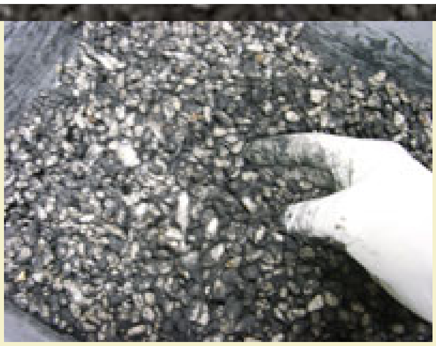

Figure 4: Mixing in the meal by hand.

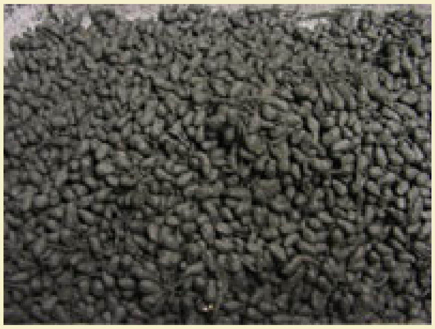

Figure 5: Finished cotton seeds are completely coated with meal.

slurry.

Because the cotton hairs on the seeds tend to get matted down and entangled with each other, the ideal process allows the seeds to be coated while also keeping them separated. This is better achieved by first wetting the cotton seeds and then introducing dry powder to them and stirring them around.

Figure 1 shows a large plastic bucket filled with dry cotton seeds to be coated. Start by spraying the seeds with water containing 14% alcohol, stirring them as you spray. You don't want to soak the seeds in a bucket of water because then they will be overly soaked and stick together. By spraying them you will be able to control the amount of starting dampness, which will be the point when the cotton is saturated and the seeds just start sticking to the bucket walls and your hands (see Figure 2).

Once the seeds are dampened, introduce the dry meal powder containing 5% dextrin as shown in Figure 3. Incorporate the powder by stirring with your hands, then keep adding more until the seeds stop picking up the dry powder.

The powder is not added onto the seeds in any particular ratio as it is for other burst charge types. It is added until the seeds are completely covered so that no white spots are visible, as shown in Figure 5. If the seeds stop picking up powder before they are fully coated, it may be necessary to spray them again before adding more powder.

Another method for coating the seeds is to use a star roller to keep from having to stir them by hand. The seeds are tumbled in the roller and alternately hit with water spray and powder.

Once the seeds are coated, lay them out to dry on sheets of newspaper or screens.

More...

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8" Crown Crysanthemum Shell

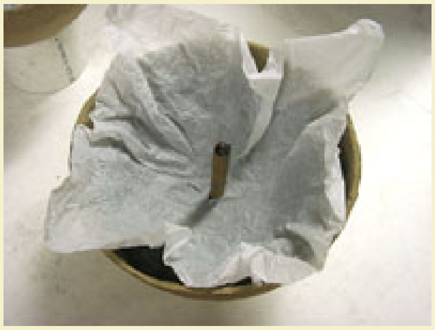
Figure 6: Tissue liner positioned over loaded stars.

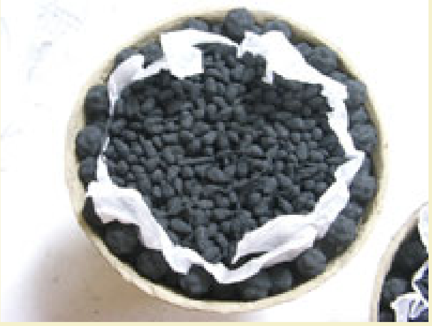
Figure 7: Cotton seed burst loaded in place.

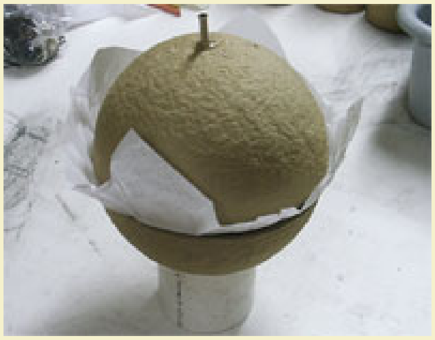
Figure 8: Sheet of tissue used to prevent spills when one shell half is inverted onto the other.

Building the Shell:

A chrysanthemum style break is defined by long streamer stars that branch out from the center, as opposed to single colored points of light that define a peony style break. A brocade chrysanthemum further defines the effect to be gold streamer stars. Any of the four formulas on the title page will produce an effect that fits this description.

While 8" shells are no more difficult or time consuming to build than a 6" shell, they do consume considerably more star composition. The stars for this shell should be rolled up to at least 3/4" diameter. If you wanted a "crown" chrysanthemum style break, you would need to roll the stars even larger in order to get the defining drooping effect caused by long burning stars. When rolling larger stars like this, it is best to dry them at intervals of 1/4", 3/8", 1/2" and finally 3/4". Rolling them up to a full 3/4" from the start would result in excessively long drying times. Rolling too much composition onto a star in one sitting can also cause the stars to break during the rolling process. This results in chunks of damp star comp breaking away from the dry core underneath, causing flat spots on the star and leaving irregular chunks of material rolling around with the other stars.

As for mixing the four compositions given here, I have found that simply screening them together gives the best streamer effect and gives a star that rolls easier and dries faster. Ball milling the nitrate, charcoal and sulfur components together before adding the remaining ingredients tends to speed up the burn rate, shortens the tail length, causes spiking when rolling the stars and increases drying times considerably. However, ball milling does achieve a finer grained tail with an almost soft, fuzzy appearance if that is the effect you want. Sometimes I will ball mill with only half the charcoal added, then add the other half after milling to try and achieve both effects.

The hemispheres used here are the vacu-form type, which can be made as described here. Figure 9 shows how round these home-made hemispheres can be produced. A 12 gallon tub of mulch will produce about three or four sets of these. Any type of hemisphere can be used however, since it is the paste layer that provides the actual containment.

The time fuse is cut to give a four second delay between cross match holes. This should be a distance of about 2" between the holes. The time fuse is cross-matched on the inside end and inserted into a hole in one hemi, such that about one inch of fuse protrudes on the outside of the shell. Hot glue is used to seal around the base both inside and outside the shell to help prevent lift gases from leaking in. A 3.5" long pipette is placed over the time fuse and cross match on the inside and pushed into the hot glue around the base while before it solidifies. I prefer to stuff this tube with scraps of black match to help insure a good blast of fire out the pipette when the time fuse burns through.

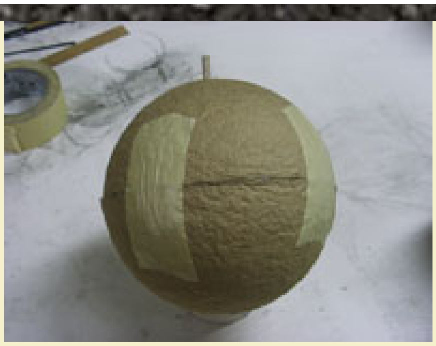

Figure 9: Halves brought together by tapping with a stick, then held with tape.

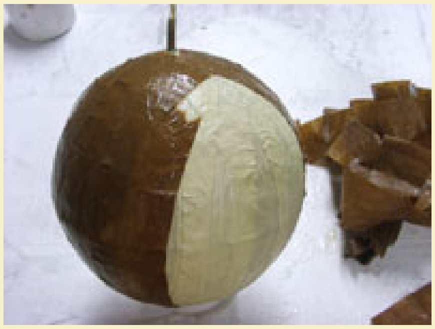

Figure 10: Alternating long and short paste strips.

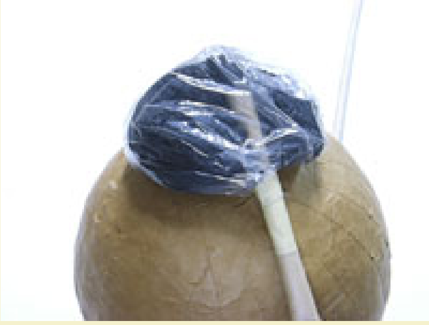

Figure 11: 120g lift bag positioned over cross-matched time fuse.

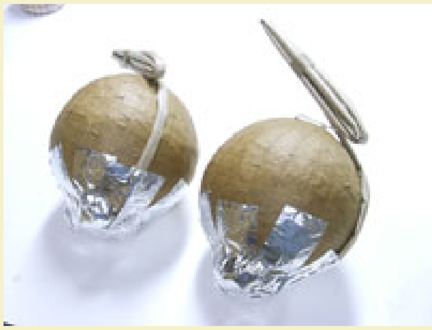

Figure 12: Foil tape used to secure and protect the lift charge.

The hemispheres are now placed on some round collars to hold them while being loaded. Line the walls with your stars until almost at the top, then place a piece of tissue over them to act as the liner between the burst charge and the stars (see Figure 6). This liner helps prevent stars from shifting into the burst charge during loading and handling.

The meal coated cotton seed is now used to fill the tissue liner until it is level with the top of the shell. The remaining round stars are now pushed in around the edge of the shell until the stars are flush with the edge of the shell. There will always be some stars a little over and some a little under, but they will settle when the shell is closed. Figure 7 shows what both halves should look like prior to closing.

This shell is still small enough to get away with using a sheet of tissue to hold the contents from falling out when inverting one half of the shell over onto the other half, as seen in Figure 8. The shell halves are settled together by rapping the outside with a dowel rod while pushing down from above. The excess tissue is torn away and the seam is held closed using masking tape. If you are using vacu-form hemispheres, then the entire shell must be covered in masking tape to protect the sponge-like nature of the paper mulch from getting soggy and caving in during pasting.

This shell is pasted in using 2" wide strips of 70lb virgin kraft. This is not a good place to skimp by using grocery bag paper. High strength paper is the key to good ball shells, and also reduces the number of paste layers required. Only six or seven layers are needed to paste in this shell, with each layer consuming about five to six 36" long strips of 2" wide paper.

I prefer the pasting procedure shown here, which works just as well for one shell being pasted by one person as it does for the many shells shown in the article. Prepare three stacks of 5 or 6 strips as shown, then apply three layers to the shell. Let the shell completely dry, then come back and do three or four more layers. Pasting all the layers at once will result in a shell that takes forever to dry and is quite mushy after pasting.

After completing the last paste layer, use three layers of pasted strip scraps to hold down a doubled up loop of cotton twine on top of the shell, which you will need when lowering this shell into the mortar. Do not try and load this shell into the gun using the shell leader to lower it down the pipe!

Figures 11 and 12 shows a simple way to lift and leader the shell. A plastic sandwich bag is filled with 120g of 2FA, then the lift bag is tapped closed around the end of a 4ft long leader. Taping the leader into the bag is preferred over tying it in, since tying tends to pinch off the gap around the black match and can cause a hang fire.

The lift bag is simply placed over the cross matched time fuse and held down with four pieces of foil tape. I prefer to use foil tape for the fire protection it provides, especially when building shells that will be hand fired from hot guns that may have smoldering pieces of paper in the bottom of them.

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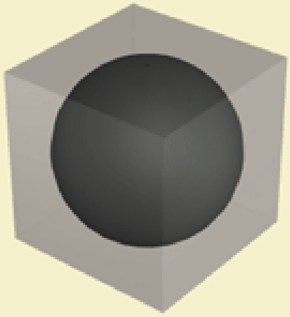
Design Notes... Page 1

Burst Charges

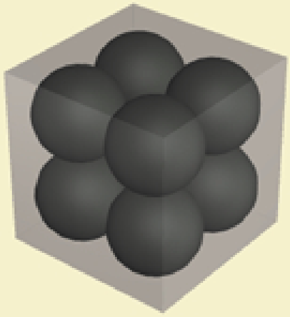
Introduction:
Unlike lift charges, there is no simple rule of thumb for finding the proper break charge for a given size shell. The type of burst charge will vary depending on the volume of space available for it inside the shell. A 3" shell has far less volume than a 6" shell, thus a stronger burst charge is needed for it. Even a 6" ring shell has considerably more volume available to the burst charge than a 6" double petal effect, due to the space occupied by the stars. So even shells of the same diameter will require different burst charges depending on space constraints.

The purpose of this article is to provide a better understanding of various types of burst charges and the parameters that dictate their usage. Once you understand the fundamentals and develop a feel for the strength of the most common burst charges, you will find that the trial and error required to produce a new shell will be greatly reduced.

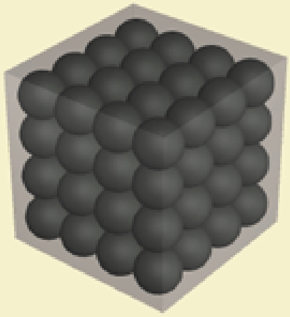
The major burst charge parameters explored here include the grain size, the ignitability of the grains, the rate of flame propagation between the grains and the burn rate of the most common burst charges.



Grain Size: 1"
Surface Area: 3.14 sq. in.



Grain Size: 1/2"
Surface Area: 6.28 sq. in.



Grain Size: 1/4"
Surface Area: 12.57 sq. in.

Grain Size:
One of the most useful methods of controlling the burn rate of a burst charge is to control the exposed surface area. This allows us to dial in the strength of a given charge without altering the formula itself. The basic idea is to process the burst charge into grains of a specific size. The grains are shaped such that there are air gaps between them, thus allowing the hot gasses to rapidly propagate between all particles almost instantly. The exposed surface area of the powder is effectively the sum total of the surface areas for each grain.

The diagram above illustrates the relationship between grain size and surface area. A spherical grain shape has been used to simplify the surface area calculation. If we had one single grain contained in a one cubic inch box, the surface area would be 3.14 square inches. If the grain size were cut in half, then eight grains would fit in the same space, giving a combined surface area of 6.28 square inches. If the grain size was again reduced by half, a total of 64 grains would fit in the same space and yield a surface area of 12.57 cubic inches.

It can be seen above that each time the grain size is cut in half, the exposed surface area of the charge is doubled. While the burn rate of the powder does increase considerably as the grain size is reduced, the burn rate increase does not correspond in a direct ratio with the increase in surface area. As the grains get smaller, the gaps between them also get smaller as well, thus creating more resistance for the hot gases trying to work their way between them.

This delayed propagation means that the entire surface area will not ignite simultaneously. Thus there is a point of diminishing returns after which the burn rate will not increase anymore as the grain size is decreased. In fact, the burn rate trend will actually reverse itself beyond a certain point. For this reason grains smaller than 50 mesh are not generally used in fireworks, and even that size is only used in small quantities so that the propagation rate is not an issue.

Grain size is an important tool for adjusting break charge strength. As shells get larger and the space to be filled by the break charge increases, the strength of the break charge must be decreased accordingly. For larger shells above 8" diameter, even downshifting to the weakest break charge (black powder) is not enough. You must slow the burn rate even further by increasing the grains size as the size of the shell increases.

Ignitability:

For lack of a better word, I am using this term to refer to the amount of time it takes a powder grain to ignite. While the round grains illustrated above made the surface area math easy to calculate, they do not make a very optimal grain shape for burst charges. This is because smooth, round surfaces do not take fire as easily as jagged grains with sharp edges. The reason for this is that heat being applied to a point on the surface of a sphere is more readily absorbed into the surrounding area, as seen in Figure 1. Because heat is being drawn away from the ignition area, it will take longer for the grain to reach its ignition point. This phenomenon is an even larger issue with round stars, since they sit at the outer edge of the flame front and have the shortest amount of time to take fire before the shell bursts.

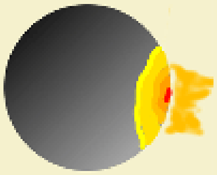


Figure 1: Heat absorption around heated spot on a sphere.

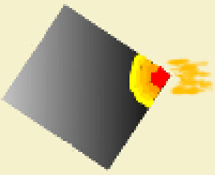


Figure 2: Heat absorption around heated corner of a cube.

Jagged surfaces and sharp corners like the one shown in Figure 2 will take fire quite rapidly, since the heat does not have any immediate surroundings to bleed into. The less mass there is to absorb heat, the faster that mass will heat up and ignite. This is why you can hold a blowtorch up to a sheet of plywood for several seconds without burning it, while the same amount of heat applied to a tooth pick would burn it up instantly. The sharp edges on cut stars and pumped stars also explains why they ignite better than round stars (although spiking the prime layer on your round stars as recommended by this site will get around this problem).

Ignitability is not usually an issue with burst charges, since they are typically rolled onto irregular shaped cores such as rice hulls or cotton seeds. There are occasions when a burst charge is rolled directly onto round stars in a shell, in which case the slower ignition must be accounted for.

More...

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Burst Charges...

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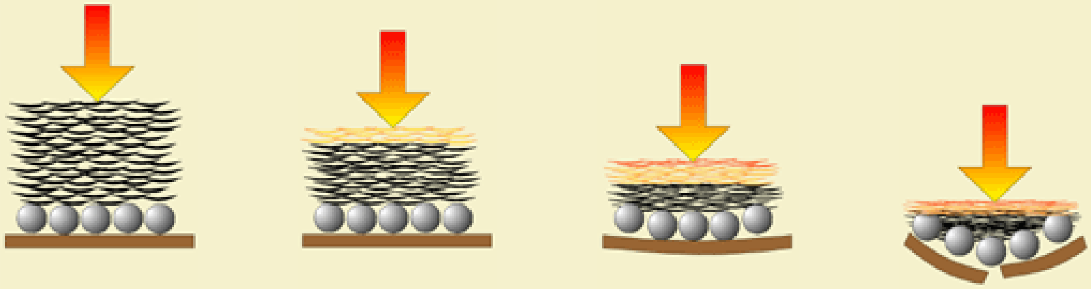
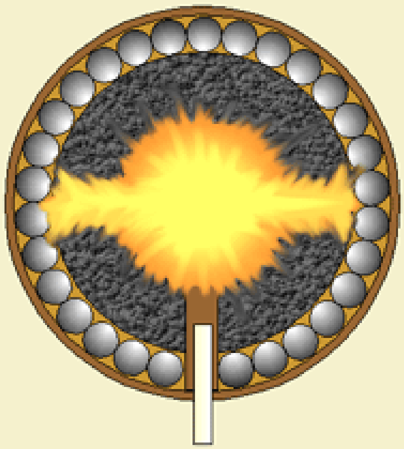
Flame Propagation:
Flame propagation refers to the movement of hot gasses between the grains in a burst charge. An effective burst charge will contain plenty of air gaps so the initial ignition point can spread rapidly throughout the entire shell before it bursts. There are three main aspects of the powder grain that will control flame propagation: size, shape and compressibility.

The effects of grain size have already been mentioned, with smaller grains leaving smaller passages that require higher pressures and longer propagation times than the big airy gaps left by larger grains.



The shape of a grain can also effect flame propagation. The worst grain shape would be a flat one, such as a burst charge rolled onto flakes of paper or oatmeal. A flat grain would tend to stack in a dense configuration that would hinder flame propagation, creating a "fire-block."

The only thing worse than a flat grain would be a compressible flat grain, which is why I think the type of rice hulls used by many hobbyists are not the best choice in many cases. A flakey, compressible charge like this can be made to work in smaller shells where the flame doesn't have that far to propagate, or it can be made to work if the burst coating is applied so thick that the charge is no longer compressible. Rice hulls also work good for cases where the space available for the burst charge is very limited, such as in a double petal type shell. However, using this type of charge in a shell where the flame has very far to travel, such as in a multi-break canister, peony larger than 5" or ring & bowtie shell of any size is just asking for trouble.



The sequence above shows what can (and does) happen with rice hull charges that are used to fill large volumes within a shell. Following the central ignition, the hot gases begin to push outward in all directions. As the gases push their way into the rice hulls, the hulls begin to compress and further restrict the available passages for the gas to travel. The more the passages get restricted, the more the pressure becomes one-sided. This eventually compresses the hulls to a point where they are just end-burning from the center outward, and the shell will often break before the fire ever gets to the stars. A rigid grain with a rounded or granular shape to allow plenty of air gaps does not suffer from this problem.

Figure 3 shows the flame propagation in a shell containing a burst charge that is too dense to allow good flame propagation. The gasses will quickly spread out along the central gap where the two shell halves meet, igniting the stars that are at the perimeter of the seam and working outwards from there. The central flame front may never reach the stars at the ends of the shell

Figure 3: Flame front of a ball shell.

before it bursts. If you ever had a shell break that seemed pretty sparse but still somewhat round, or a ring and bowtie shell where the bowtie was blown blind but the ring lit, this is the likely cause.

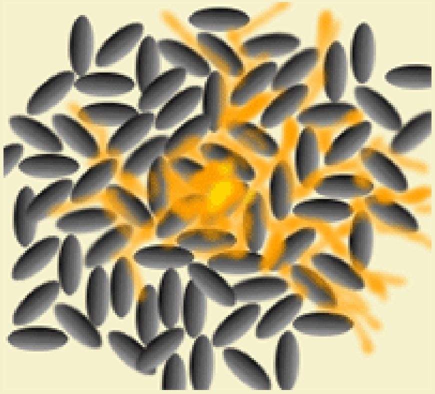


Figure 4: Flame propagation through puffed rice break charge.

Figure 4 shows a simulated flame propagation between the grains of coated puffed rice cereal, my favorite burst charge core for 6" and 8" shells. This charge is very rigid, leaves lots of air gaps and is very light weight (thus saving you lift powder). This charge is also much closer in appearance to the rice hull charges used by the Chinese in commercial shells of the same size range.

More...

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Burst Charges...

Page 3

Burst Charge Types:
As if there were not enough variables to keep track of at this point, the following information outlines five of the most common break charges in order from strongest to weakest. The rule of thumb is to use stronger charges for smaller shells and weaker charges as the shell grows in size. If your shell bursts with uneven symmetery, then the burst charge needs to be strengthened by making the grains smaller, using more charge or by using a stronger charge (making the casing stronger also helps fix the problem). If the shell breaks too hard or stars are blown blind, then the burst charge needs to be cut back by using larger grains, using less charge or using a weaker mix.

Flash:
Flash is the strongest of all burst charges and must be used in moderation. There are various flash formulas used for breaking shells, each designed for a specific break system. Straight 7-3 Flash is the strongest option that will produce the hardest breaks. Variations on the basic flash formula often add other components such as sulfur and antimony, sometimes called "dirty flash" formulas. These burn less fiercely than flash and have less problems with blowing stars blind. The Ofca Flash attempts to improve star ignition by driving droplets of molten antimony into the stars, and is considerably slower burning than other flash formulas.

Preperation
Formulas: Standard Flash, Bleser Flash, Ofca Flash

Extreme caution should be used when mixing flash formulas, especially those containing dark aluminum such as German or Indian black head. Fine aluminum and potassium perchlorate are a friction sensitive combination, thus screening or any kind of grinding action should be strictly avoided. Flash formulas containing American dark aluminum (809) are not as sensitive due to the stearine coating on the aluminum, and they are less likely to over break the shell as well. All flash formulas are also sensitive to static electricity, so care must be taken to avoid mixing in dry climates and to ground yourself before working. Individual components should be pushed through a screen separately and then diapered together using a sheet of paper to rock them back and forth until adequately mixed.

Usage
Flash can be coated onto rice hulls for use in smaller shells under 3", but it is most commonly employed using a flash bag to locate a small amount at the center of the shell. A flash bag can be a paper or plastic bag containing a small amount of flash, which is tied off to the time fuse. A simpler method is to place the flash on a small sheet of tissue paper, then pull the corners together and twist them to form a little bag that is placed at the center of the shell. For smaller shells the flash bag method allows more stars to be used, but this becomes a costly feature as the shell size increases. In shells between 4" and 6" flash is most often used as a booster in addition to another type of burst charge that fills the empty space. The use of flash is not recommended for shells larger than 6". Flash breaking shells has the disadvantage of creating a very bright flash that can cause spots in the eyes of the viewer, and is not recommended for any delicate streamer effects.

Whistle:
Whistle mix is second in line for burst strength after flash, and has the advantage of not creating the bright flash that flash does.

Preperation
Formula: Whistle Burst

Unlike flash, the components of whistle mix can be safely screened together. Ball milling should be strictly avoided though. The sensitivity to static electricity is the same as for flash and the same precautions must be taken to avoid it. Whistle mix made from sodium salicylate will provide a stronger burst charge than that made from sodium or potassium benzoate. The formula is the same regardless of which fuel you use: 70% potassium perchlorate mixed with 30% potassium benzoate, sodium benzoate or sodium salicylate.

Usage

Whistle mix is used in the same way that the flash burst charges are used. It can be coated onto rice hulls for small shells, used in a central "flash bag" tied to the time fuse, or loosely added as a booster to another burst charge type. Because whistle is safer to mix and store, and does not produce the distracting white flash, it is a more desirable alternative to flash breaking shells.

H3:

H3 is a powerful burst charge originally published in Shimizu's Fireworks- Art, Science and Technique. It generates an explosive force about 2.4 times stronger than black powder. Unlike KP, the burn rate of H3 is not dependent on pressure and it burns quite rapidly in open air.

Preperation

Formula: H3 Burst

The simple formula consists of 75% potassium chlorate and 25% charcoal, with the addition of 2% glutinous rice starch or dextrin to help it adhere to whatever cores it is to be rolled on. The components can be safely screened together, but ball milling should be strictly avoided. H3 is most commonly rolled onto rice hulls in a ratio of 4:1, or it can also be riced into granular form using the same method as for producing rough powder. Using the granular form is ideal for shells 2" in diameter or less. When using the granular form it is important to maintain grain size consistency, as the strength of the charge will be highly dependant on grain size and failure to control this variable will give you inconsistent results in your shells.

Usage

This charge is most often used in smaller shells that require a more energetic burst charge to function. It can be used in 2.5" and 3" plastic shells without the need for additional flash or whistle mix boosting. It also makes a great burst charge for 5" spider shell canisters, which allows the stars to be blown out hard in straight lines without the retina spotting white flash you get from using flash bags to achieve the same effect.

Some builders are deterred from using this charge due to the presence of chlorates. However, as Shimizu notes, this charge is "unexpectedly insensitive to shock and friction." Repeated drop tests showed it to be only slightly more sensitive than black powder, but less sensitive than KP! However, if it comes in contact with sulfur containing compounds, it becomes highly sensitive. A shell containing H3 that fails to burst and falls back to the ground will often detonate on impact if there is no barrier between the H3 and meal coated stars in contact with it. Thus it is wise to keep the H3 from coming into contact with any meal coated stars using tissue paper barriers.

KP:

The KP burst charge was developed in 1955 as an alternative to the chlorate containing H3 charge. While it is not strong enough to replace H3 in shells smaller than 4", it makes a great burst charge for shells in the 4" to 6" range. The advantage over H3 is that there are no sensitivity issues when coming into contact with meal primed stars.

While the explosive force generated by an equivalent amount of H3 and KP are about equal, H3 burns three times faster than KP in open air. Even black powder burns two times faster than KP in open air. Igniting a small sample of KP on the ground would lead one to believe that it burns too slowly for use as a good burst charge. How is it then that KP performs so well?

The distinctive characteristic of KP is that its burning rate substantially increases as the surrounding pressure is increased. Thus KP burns much faster inside the shell as the pressure builds up than it does in open air. Because of this characteristic, the strength of a given charge can actually be adjusted by increasing or decreasing the thickness of the shell wall. It is in fact possible to build a 3" shell using KP that breaks with the same force as one using H3, it's just that the KP shell would require a thicker wall to the point that the extra pasting would not be worth the trouble.

Preperation

Formula: KP

The formula for KP given by Shimizu is 70% potassium perchlorate, 18% charcoal and 12% sulfur with an additional 2% glutinous rice starch or 5% dextrin added to help the material stick to whatever core it is rolled onto. Using the same 75-15-10 formula as for black powder also works well, making a simple substitution for potassium nitrate using the perchlorate. All compounds can be safely screened together and should be mixed well. I prefer to ball mill the sulfur and charcoal components together, then screen in the perchlorate. The full mix should not be ball milled however, as KP is more sensitive to friction than black powder.

Usage

KP is most often rolled onto rice hulls or similar sized cores. It is ideal for usage in shells in the 4" to 6" range, as it is too strong for shells larger than 6". KP is also an effective burst charge for rolling directly on the stars, as its fast burn rate under pressure makes up for the exposed surface area lost when rolling onto large cores such as the stars themselves.

BP (black powder):

This is the oldest, cheapest, safest and the weakest burst charge. BP is the charge of choice when large volumes of burst charge are required, such as 6" ring shells, 8" single petals and all shells 10" and larger. BP has only half the explosive force of KP or H3, thus a lot more of it is required to break a given size shell.

Preperation

Formula: Black Powder

Black powder requires much more work to produce compared with the other break charges listed here. The type of charcoal used plays a major role in the strength of the powder, and all components must be intimately mixed using a ball mill or similar grinding method. For use in burst charges, the standard 75-15-10 formula is used with the addition of 5% dextrin for binding purposes. It is easiest to ball mill the dextrin along with the other three components rather than trying to screen it in with milled meal powder later. Full details for producing high quality BP can be found here.

Usage

For mid sized shells BP is most commonly coated onto rice hulls or similar cores. I find 4:1 BP/puffed rice the best choice for 6" ring shells or 8" single petal shells. For larger shells, cotton seeds are the core of choice due to their larger size, low cost and ease of preparation. The fuzzy seeds allow the powder to strongly adhere to the surface, and they dry easily as well. For more details on coating cotton seeds, click here.

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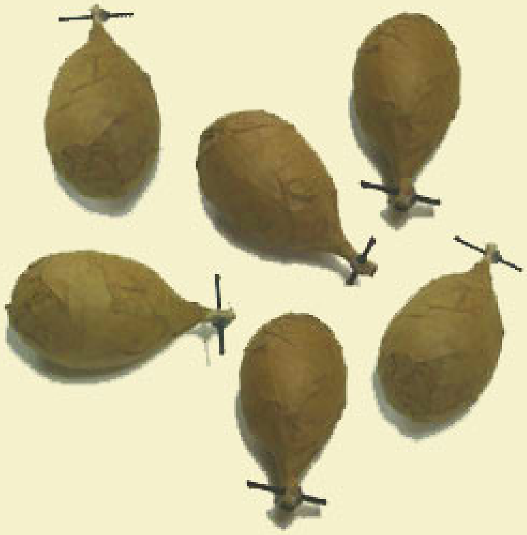
Volume 2, Issue 8

Build This...

2" Easter Egg Shells



August, 2002 Issue

Build This:
2" Easter Egg Shells

Design Notes:
Time Fuse and Spolettes

Tool Tip:
Cross Match Punches

Autopsy:
4" Canister: Color w/Strobe Reports

NEW! Shell Burst Simulator

Summary:
The use of plastic Easter eggs is a quick and cheap means for producing small shells that perform surprisingly well. While this type of shell is a good choice for first time shell builders, they also prove quite effective as rocket headings, girandola headings, multi-tube cake loads and even inserts for larger round shells. The oblong shape does not reflect itself in the break pattern, which tends to be more symmetrical than film canister shells or even paper canister shells of the same diameter.

Formulas: Whistle Mix

Materials:

- (1) 1-3/4" O.D. plastic Easter egg shell
- (1) 3/8" ID x 1-1/4" long thin walled paper tube
- (2) 7" long strips of fiber reinforced tape
- (1) 4" x 12" strip of 30lb kraft

Tools:

- 7/32" drill bit
- Cross match punch
- Hot glue gun
- Utility knife

Unmeasured Materials:
Time fuse, cross match, whistle mix, 1/4" to 3/8" stars.

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2" Easter Egg Shells...

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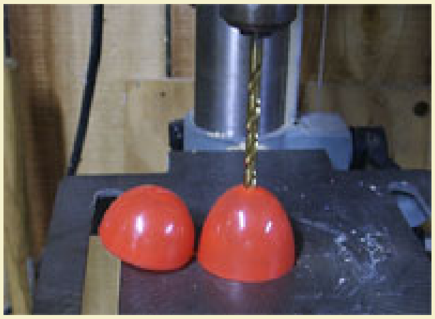
Figure 1: Drilling 7/32" time fuse hole.

Introduction:
The use of Easter eggs for making small aerial shells is nothing new, as they are ideally suited for this purpose. Unlike film canister shells, which are another popular small I.D. shell made from the small plastic cans that film is packaged in, Easter eggs are easier to acquire in large numbers. Even though they are not perfectly round, the break achieved with them is comparable to shells made with commercial plastic hemispheres of the same size. While they are only on the market a few months each year, Easter eggs are typically sold in large bags for a reasonable price. The only difficult part is buying enough of them to last the whole year!

There are two types of plastic commonly used in Easter eggs: styrene and polyethylene. Styrene is a stronger, more brittle plastic that most Easter eggs were made from in the past and is ideally suited for making shells. Unfortunately, styrene eggs are getting harder to find. Polyethylene eggs, which are more pliable and slightly transparent, have all but replaced the styrene variety. Thus, the construction method shown here has been designed to achieve good performance using polyethylene eggs.

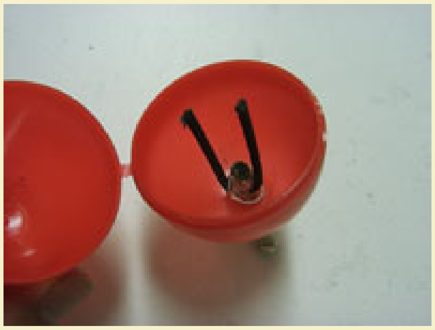
Figure 2: Cross matched time fuse in place.

Construction:
The newer polyethylene eggs come with a small hinge that keeps both halves attached, which actually makes assembly a little easier. Begin by drilling a 7/32" hole into the bottom of the larger shell half, as seen in Figure 1. This size hole will provide a very snug fit for standard Chinese time fuse. Any burrs left from the drilling will need to be removed or it will interfere with inserting the time use.

Using a length of time fuse appropriate for your application, cross match one end with a 2" long stick of black match. If you will be shooting your shells from a small mortar, a length of about 1" between cross match holes will provide good timing. The second cross match hole is not punched until after the shell is completed. Twist the time fuse into the shell half until the cross match nearly hits the bottom, as seen in Figure 2. Care must be taken not to cut your hands on plastic burrs when doing this. After the fuse is positioned, use hot glue to seal around the external end of the time fuse. This helps insure that no hot gasses leak in around the sides of the fuse when the shell is under the pressure of lift or burst gasses.

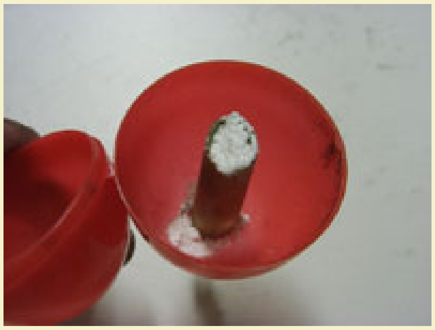
Figure 3: Center tube filled with whistle mix.

A small paper tube made from a few turns of 50-60lb kraft around a 3/8" former is placed over the cross match and slid down onto the time fuse. The tube should be level with the rim of the shell half and does not need to be glued to the bottom of the shell. The purpose of this tube is to contain the burst charge as well as make sure the ignition point is at the center of the shell. Several tests on shells with and without the center tube indicate that it is an important component for achieving a good break pattern.

A burst charge of 70-30 type whistle mix is used to fill the inside of the tube, as seen in Figure 3. If the shell will not be used immediately, it may be a good idea to glue a small piece of tissue over the tube to insure that the burst charge does not migrate out of the tube and mix with the stars.

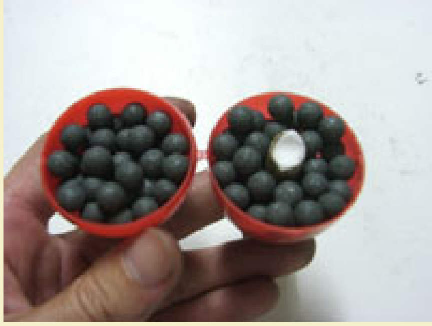
Figure 4: Round stars fill remaining space.

With the burst core completed, the remaining space is filled with the stars of your choice. The stars can be round, cut or even pumped, ranging in size from 1/4" to 3/8" depending on the effect desired. Figure 4 shows 5/16" round stars being used.

Once the shell is loaded, it is closed by quickly inverting the smaller half over onto the half containing the burst charge. Some tapping will be required to get the stars to settled and allow the seam to fully close. The stars should not be able to loosely roll about inside the shell.

It is not necessary to apply glue to the seam for holding the shell together, although a band of masking tape will help to keep the shell from accidentally popping open during assembly. The weak point caused by the seam is compensated for by two 7" long strips of fiber reinforced packing tape that wrap one complete turn around the shell as seen in Figure 5. The strips are applied perpendicular to each other so they form an X at each end. A utility knife is used to cut a small slit at the center of each strip so that the time fuse can protrude through it. These tape strips provide considerable strength in the long direction, preventing the shell from simply popping in half at the seam.

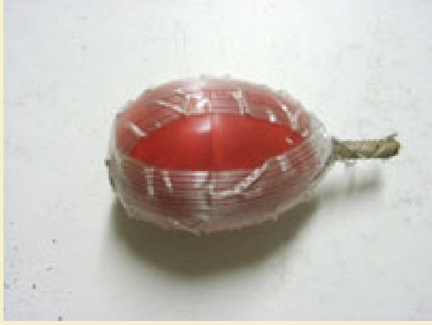
Figure 5: Fiber tape for longitudinal reinforcement.

More...

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2" Easter Egg Shells...

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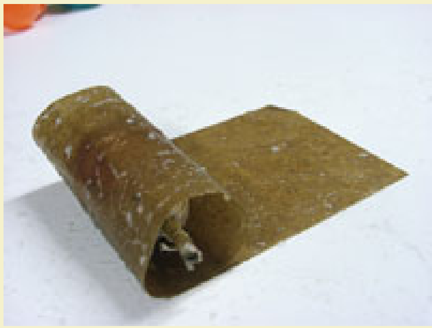

Figure 6: Rolling on two turns of pasted 30lb.

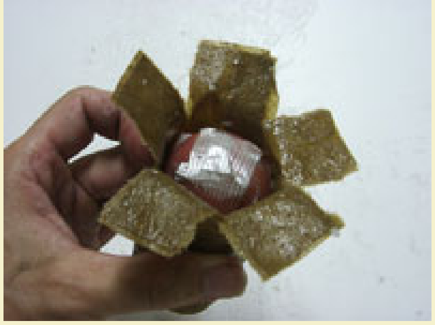

Figure 7: Pleating paper over each end.

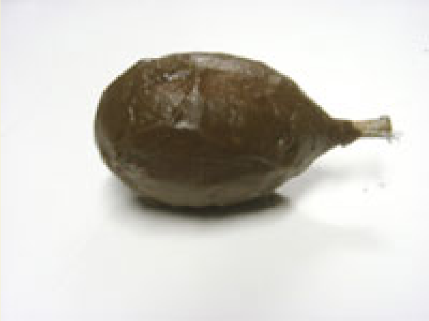

Figure 8: Paper smoothed down and ready for drying.

Pasting:

There are a number of reasons why a few turns of pasted paper around this shell will improve performance. Polyethylene provides poor containment by itself, tending to easily tear instead of break into fragments. The fiber tape already in place helps fix this problem, but a paste layer further improves the containment needed for a symmetrical break.

If this shell is to be used as an insert inside of a larger shell, then the paste layer is absolutely essential. The high temperatures and pressure inside a shell prior to burst is not a friendly environment for plastic shells, as they tend to melt and pre-detonate. The pasted paper provides rigidity so that heated plastic can not collapse, and also provides an extra barrier for gas entry around the seam and time fuse.

One might also take note that this shell is not particularly attractive in Figure 5. A paste layer provides the benefit of hiding this ghastly shell from those who might cast a critical eye at your deviation from traditional materials!

This shell will still function without any paste layer when being fired singly from a mortar, although the break will be less attractive. Omitting the paste layer allows the shell to be fired immediately, which is useful for quickly testing a batch of stars or even to satisfy a pyro fix when you have no product on hand. In this case it is necessary to put a band of masking tape around the seam prior to applying the fiber tape in order to prevent lift gases from getting into the seam and causing a flower pot.

Pasting in this shell need not be a labor intensive ordeal involving strips, as is the case when pasting larger round shells. The shell is simply rolled in two or three turns of thin kraft as if making a canister shell. The ends are then torn into tabs and pleated down to seal both ends, as seen in Figure 7. The use of recycled kraft actually helps the paper lay down better without effecting the performance. If the shell is to be used as an insert, then more than two layers may be required. The larger the shell is that will contain the inserts, the longer the inserts will be exposed to high temperature and pressure prior to being thrown from the shell.

Once the shell is pasted and dried, the time fuse is punched and cross matched. Figure 9 shows the punch described this month being put to use.

If you wish to fire your egg shells one at a time as stand-alone shells, Figure 10 shows everything you will need. Rather than attach the lift and leader to such a small shell, it is easier to prepare small lift packs using tissue paper to hold your lift powder. A mortar is bottom fused with a piece of raw black match, then the lift pack is dropped into the tube, followed by the shell. The shell can be oriented with the fuse on the top or the bottom, it will ignite either

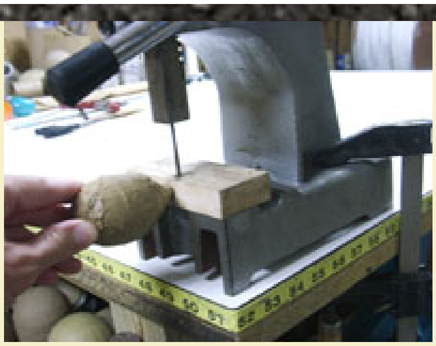

Figure 9: Punching crossmatch hole after case dries.

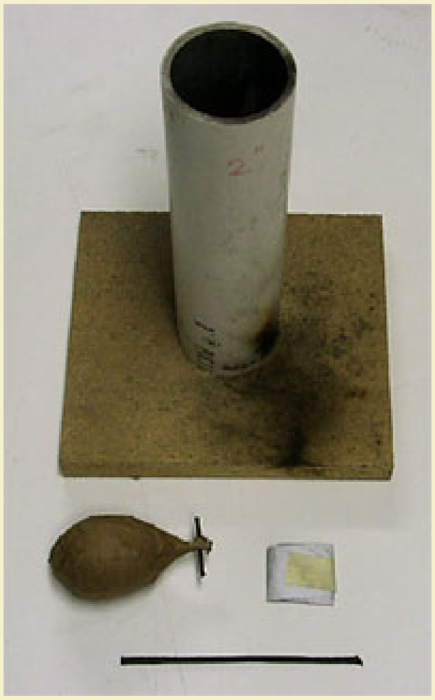

Figure 10: PVC mortar, lift pad, black match and shell ready for testing.

way. The black match will burn through the tissue paper and ignite the lift, which should be between 8 and 10 grams of 4FA for this particular shell. The lift can be weighed out and packaged into small squares so that there is only a single layer of tissue around the powder. Black much must be used with this method, as visco does not provide enough side spit to burn through the tissue reliably.

When firing successive shells, be sure all sparks are extinguished before loading the next shell. Stubborn sparks can be removed by throwing a handful of sand into the mortar and swishing it around before dumping it back out.

The mortar shown here is a 10" long piece of 2" PVC that is plugged with wood at the bottom. This mortar should not be used to fire salutes of any kind, as a misfire would send PVC shrapnel in all directions with the potential for severe injury. Star shells do not provide enough force to detonate a PVC mortar, but cardboard or HDPE is still recommended as the safest type of mortar to use.

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Tool Tip... **Page 1**

Gummed Tape Ball Shells

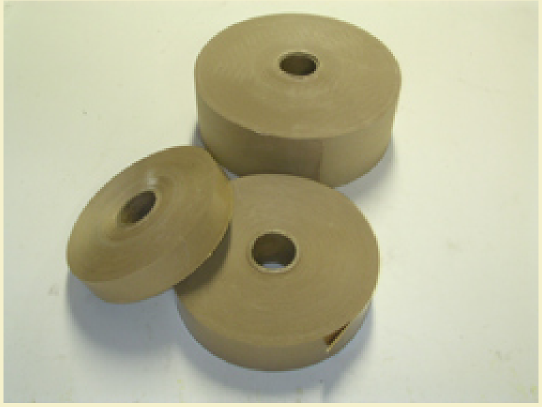

Figure 1: 1", 1.5" and 2" rolls of gummed tape.

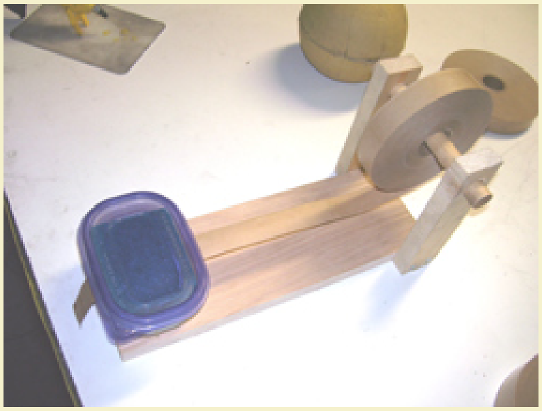

Figure 2: A simple tape dispenser that wets the gum as it is dispensed.

Introduction:
The traditional pasting process of forming the outer casing of paper ball shells, which requires cutting thin strips of paper, breaking them in with paste and then painstakingly applying them one at a time for layer after layer, has always been a deterrent to those who don't have the time or patience to make paper ball shells. The entire process usually takes about 45 minutes just to make one 6" ball shell, and progressively longer as the shell size increases. Since paper casings have very high tensile strength while being very light weight, they invariably produce the most consistently symmetrical star patterns with a very low incidence of flower potting. While paper is the casing of choice for anyone wishing to make the highest quality ball shell, the time consuming and tedious nature of the pasting process drives many pyro hobbyists to use plastic shells instead. Plastic is far more finicky when trying to achieve consistent performance, as it requires a harder-hitting break charge that puts stars right on the edge of being blown blind. One gap in the glue joint or time fuse seal results in a flower pot. Even when everything goes well, plastic shells leave a field of sharp edged plastic shards that take many years to degrade and can be hazardous to the cattle that graze on many shoot sites. From an aesthetic viewpoint, plastic shells are also just plain ugly to look at and stink up your shop with the foul smell of solvents when building them.

In the quest for taking the tedium out of ball shell construction without resorting to plastic shells, the use of gummed tape to replace the layers of pasted paper has become quite popular in recent years. Gummed tape costs about the same as the equivalent sheets of virgin kraft paper, does not need to be cut into strips and is much cleaner and faster to apply. While gummed tape is not as strong as pasted virgin kraft paper, the burst charge is usually strengthened accordingly to compensate for this fact. A gummed tape shell that performs just as well as a traditionally pasted shell can thus be constructed in a fraction of the time. Now there is even a computer controlled bench-top pasting machine on the market for the pyro who has the money to spend, which automatically applies any number of tape layers to a whole range of shell sizes (known as the WASP3). Since gummed tape has been the commercial method of choice for domestic shell manufacturing for years, it is surprising that the WASP series of machines has not caught on more as a way to help compete against Chinese imports.

The method of gummed tape construction shown here is about the fastest manual method of making a paper shell that exists. A flash booster is used to reduce the required amount of tape layers to

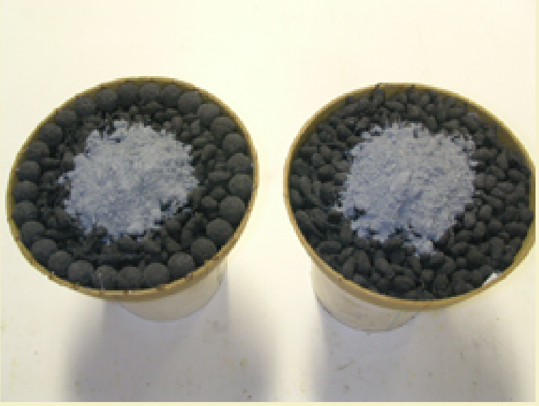
Figure 3: Flash booster poured loosely into the shell after loading.

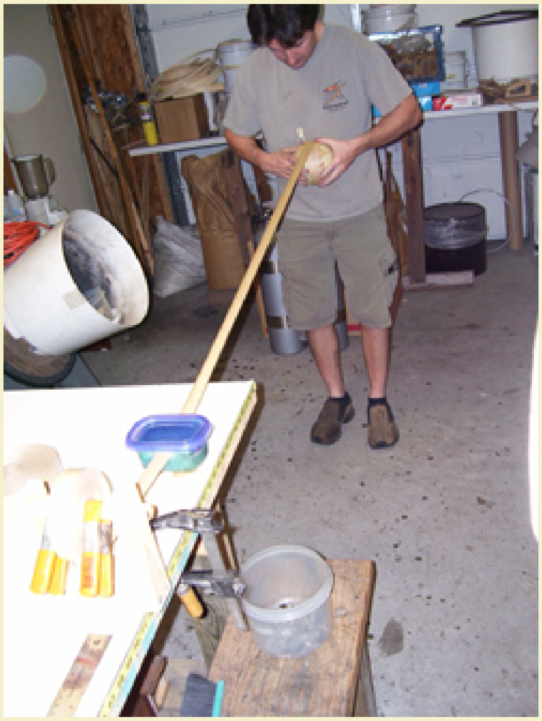
Figure 4: Setup for taping medium sized shells.

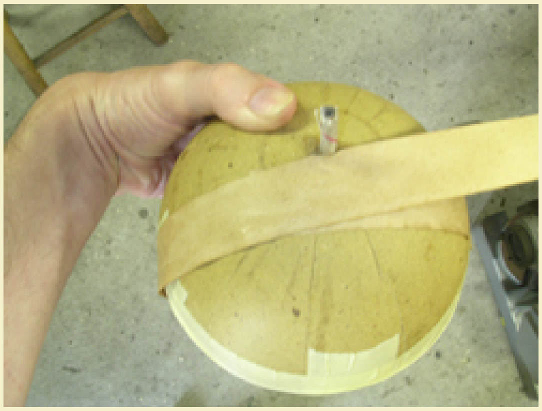
Figure 5: One loop around the shell.

about half, so you save both tape and time while spending a little more money on the burst charge. The tape dispenser and roller tools seen in this article can be built as described here. Gummed tape is ideal for shells 6" or larger, but tends to be more difficult with smaller shells since the tape does not lay down as well on a tight curve as pasted paper does. For smaller shells it is best to just stick with the traditional pasting method, which goes pretty quick on small shells anyway.

NOTE: due to the decreased number of layers and lowered strength of the gummed tape casing, vacu-form hemispheres can not be used to build this type of shell. The casing would be very susceptible to getting crushed from the lift force if using vacu-form hemispheres, so commercial hemispheres are required.

Loading the Shell

The shell is constructed just as it would be if you were going to paste it in with paper. If you normally use KP on rice hulls or puffed rice cereal, you can actually drop back to BP on rice hulls or puffed rice and save some money there. The flash booster has quite a kick to it, so the hull charge is mainly just for filler and to increase flame propagation. The flash used here is a mixture of potassium nitrate, aluminum and sulfur given here. While not as strong as a perchlorate flash, this mixture still has plenty of thump and all the same sensitivity to static, so take the same precautions.

The flash is simply poured loosely into the center of each hemisphere after it has been loaded, as seen in Figure 3. If the flash piles up too high at the center, it can be spread out as needed or you can tap the shell so that it settles. For a 6" shell, 20 to 25 grams of flash are used. For an 8" shell, 40 to 60 grams are used. I go with the low number on my shells, but it depends on how strong or thick your gummed tape is and how big you want the shell to break. Note that this flash booster is a critical component, and trying to substitute with KP or a few more layers of gummed tape isn't going to give good results. The hard break provided by the flash is the key to making these shells work, just like with plastic shells. The gummed tape is really just there to give a minimal amount of containment and help prevent the shell from being sheered in half during the lift.

The shell halves are closed in the standard way, using a sheet of tissue over one half to hold the contents from spilling while inverting it onto the other half. The excess tissue is torn away and the seam is taped closed with two continuous bands of masking tape.

Taping the Shell

If you have a good virgin kraft type of tape, you can actually get away with using 30lb tape, which lays down with less wrinkles than the 60lb tape being used here. I prefer the 60lb tape however, since it is easier to find average quality 60lb tape than high quality 30lb tape. The tape being used here is from Intertape Polymer, which was recommended to me by Jeff Doty (who also uses it to his own shells). For 6" shells the strips should be 1" wide, while 8" shells can use a 1-1/2" wide strip and larger shells can use 2" wide strips. As with pasting, the larger the shell is then the wider the strips can be without running into excessive wrinkling problems.

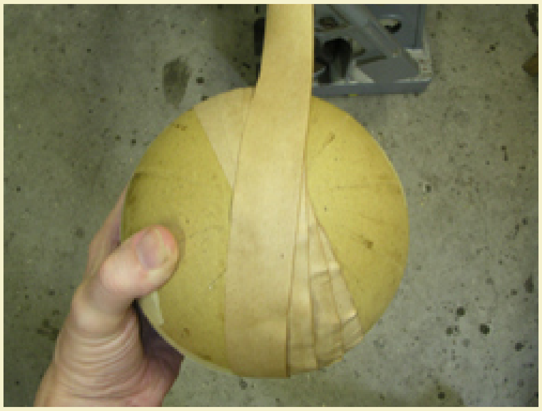
Figure 6: Strips crossing the opposite pole.

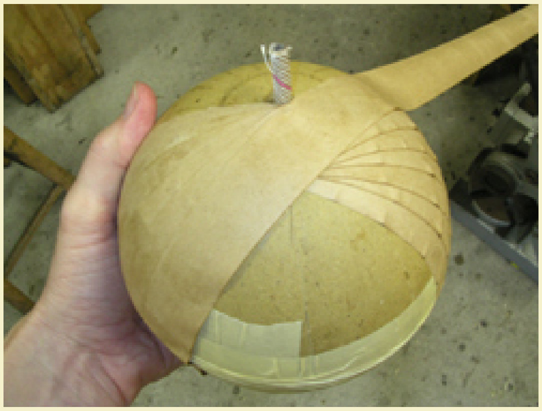
Figure 7: Several passes around the shell.

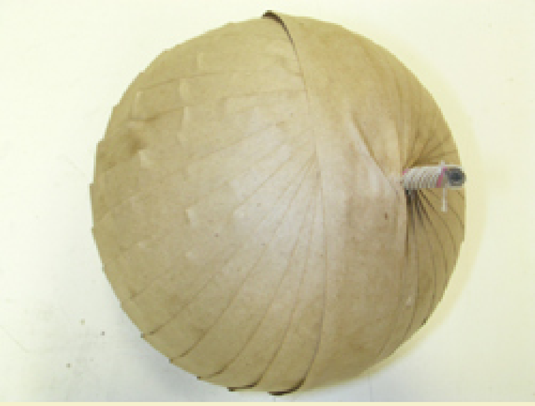
Figure 8: One complete layer before rolling out the wrinkles.

A tape dispenser similar to the one shown in Figure 2 is necessary when taping shells as described here. This dispenser will allow one continuous strip to spool out and pass through a container of water, passing between a set of sponges inside the container so that the gum side of the tape is wetted when it comes out the other side of the container. Instructions for building this tape dispenser can be found here.

The dispenser is clamped to the edge of a table as seen in Figure 4, while the shell is held by the worker in a standing position. For larger shells, the alternate setup using a tripod of roller bearings to hold the shell is used, as seen in Figure 15. This setup is discussed more below.

The tape is started to the right of the time fuse and looped around the shell so that it passes directly over the opposite pole. When the tape returns to the pole it started at, it must be guided a little off center, since the crossing points will be off to the right side of the time fuse. Figure 5 shows how the first loop looks when completed.

Each loop of tape will overlap the previous loop by one half at the equator, so as you begin the second loop it will start by covering the previous strip by 100% and then angle away from it so that by the time you reach the equator only 50% is covered. Then as the strip heads back up to the opposite pole, it is angled back in so that by the time it crosses the opposite pole it crosses directly over the previous strip. The concept is easy when you see it, but difficult to describe with words. Another way to think of this process is that you are basically "spiking" the shell using a strip of paper instead of string. So you would run the paper in a crossing pattern just like you would if you were spiking a canister shell.

Figure 6 shows show what the crossing point looks like on the opposite pole, while Figure 7 shows several loops completed. You will notice that since the paper overlaps more at the poles and less at the equator, you will get an egg shaped buildup of paper. However, the amount of buildup for just a single layers is not that noticeable, and will not effect the symmetry of the break because 1) you are only applying three layers, 2) the buildup points will be moved to a new location on each layer so that they are symmetrically distributed and 3) the shell is being hit hard with a flash break and is thus less sensitive to inconsistencies in the case wall.

Once the taping pattern has worked all the way around the shell and back to where it started, tear off the strip and roll the shell around on the table to get out the wrinkles. Figure 8 shows what a layer looks like before smoothing out the wrinkles. Note that there are more pronounced wrinkles on one half of the shell while the other half is a lot smoother. This is because one edge of the strip lays down flat as you apply it, while the other edge usually doesn't. To flatten out the wrinkles, simply hold the shell firmly against a table top while rolling it around. Figure 9 shows the first layer after flattening, which really isn't noticeably egg shapped.

The next layer is started with the poles located on the equator where the shell seam is. This layer is a little more tricky to apply, since you

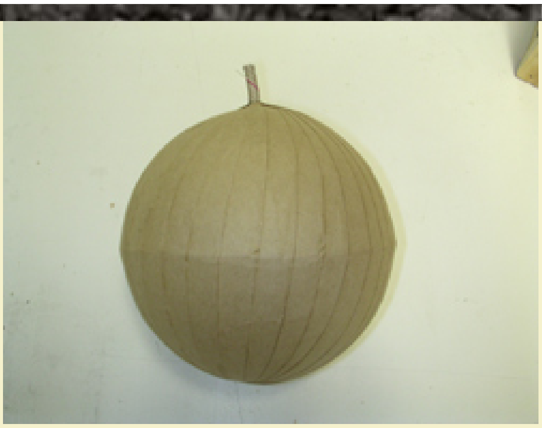

Figure 9: First layer after rolling out the wrinkles.

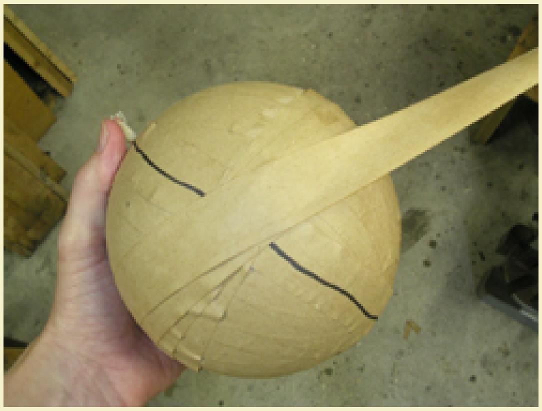

Figure 10: Starting the second layer, using a reference line to help locate the proper poles.

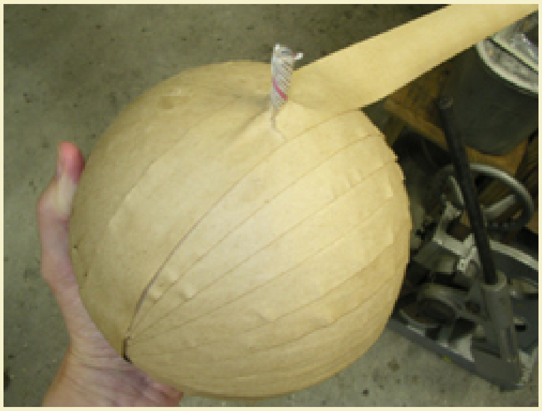

Figure 11: Tearing the strip to work around the time fuse.

no longer have the shell seam or time fuse to help guide you. It helps to draw a line perpendicular to the direction you will be applying the strips, as seen in Figure 10. This line helps show where the crossing points should be, otherwise it is pretty easy for the poles to slowly drift out of place and really mess up the tape pattern. When doing the second and third layers, you also have to work the tape around the time fuse when the strip progression reaches it. The best way to do this is to just tear the strip in half right where it reaches the fuse, then replace it on the other side as seen in Figure 11.

The third and final layer is also located on the equator, but perpendicular to the previous layer as seen in Figure 12. Figure 13 shows the completed shell with circles around the spots where the crossing points overlap. This pattern places the buildup points at six equally spaced locations on the shell.

When using 60lb tape, three layers is about the most you can put on the shell before it will no longer fit in the mortar. This is because the crossover points at the poles will have so much buildup that they fully occupy the available clearance around the shell. There will still be space between the buildup points to route your shell leader down to the lift charge without worrying about the shell not fitting in the mortar, but care must be taken not to run the leader right over one of the humps.

Taping Larger Shells

When you start getting up to 8" shells and above, the weight of the shell becomes very tiresome to try and tape while holding it in your hands. The rolling fixture shown in Figure 15 allows you to rest the shell in this cradle and spin it as you work, making the process much easier. The plans for building this fixture can be found here.

When using a rolling jig to hold the shell, the time fuse can not be installed until after the taping is complete, since the fuse would continually get in the way of the roller bearings. Thus when loading the shell, the time fuse is not glued in place. Instead, a hollow tube with tissue paper glued over one end is hot glued over top of the time fuse hole. Once the shell is closed, a flat head nail is placed into the hole and covered with a piece of masking tape as seen in Figure 14. This allows you to find the fuse hole using a magnet after the shell has been taped in. If you don't have a nail head large enough to keep the nail from falling into the hole, you can put a washer under the head. The washer also provides some extra metal to help with the magnet detection.

Immediately after the shell is done being taped, the nail head is located with the magnet and marked with a circle. A sharp utility knife or Exacto blade is then used to cut out the circle so that the nail can be removed. Care must be taken to be sure you have the right spot, otherwise you will be cutting a hole in the side of your shell!

After the nail has been removed, 2Fg black powder is poured into the hole until the tube is filled to a level that allows the time fuse to stick out a at least 3/4" from the shell. The inside end of the time fuse can not be cross matched, so you will just cut it at a 45 degree angle and push this solidly into the black powder grains. The timing interval will be measured from the center of the 45 degree cut, then the other side of the fuse will be cut at least 1/4" longer than the timing interval so that the outside end can be cross matched in the usual way.

Once the time fuse is inserted, a generous amount of hot melt glue is sealed around the base to make sure no fire sneaks in around the fuse and sets off the shell during lift. The glue should be coned up around the base of the fuse also, which helps keep it from being blown into the shell.

More Shells, Less Time

After some practice getting used to applying the continuous strip pattern, you will find that a shell that might have once taken 45 minutes to paste now only takes 10 minutes to tape and the performance is exactly the same! Even a die-hard traditionalist will have a hard time arguing against that kind of productivity gain. It is interesting to note that all the big 16 inch brocade shells that appeared in the 2006 PGI convention were gummed tape shells, so there is no size limitation with this method either. Personally, this is how I build all my shells 6" and up now. Once you experience the speed, you just can't go back to pasting! 🔥

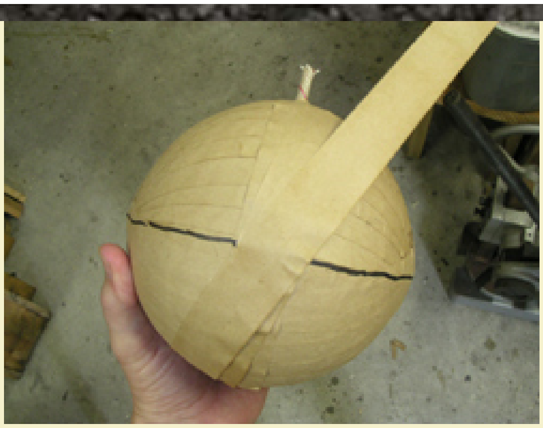

Figure 12: Starting the third layer, using another reference line to help keep the strips in the proper pattern.

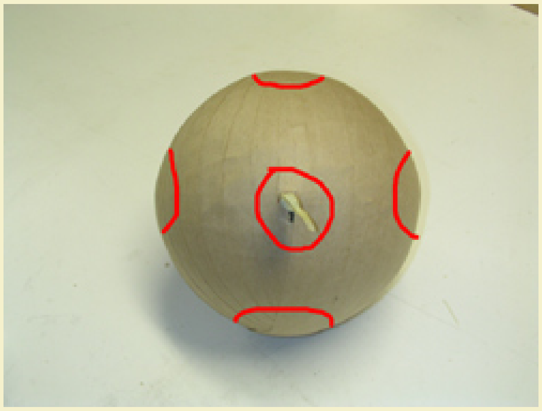

Figure 13: Completed shell, with red circles showing where the overlapping buildup points are located.

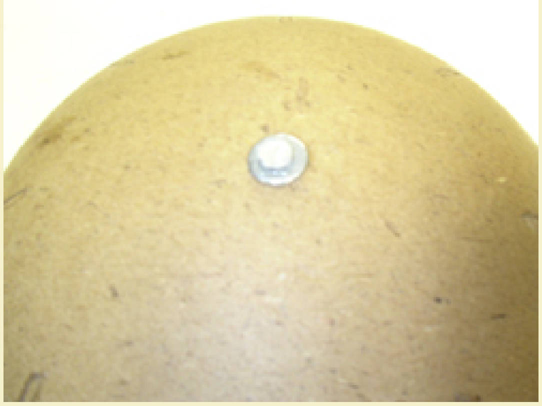

Figure 14: Plugging time fuse hole with a temporary nail before taping an 8" shell.

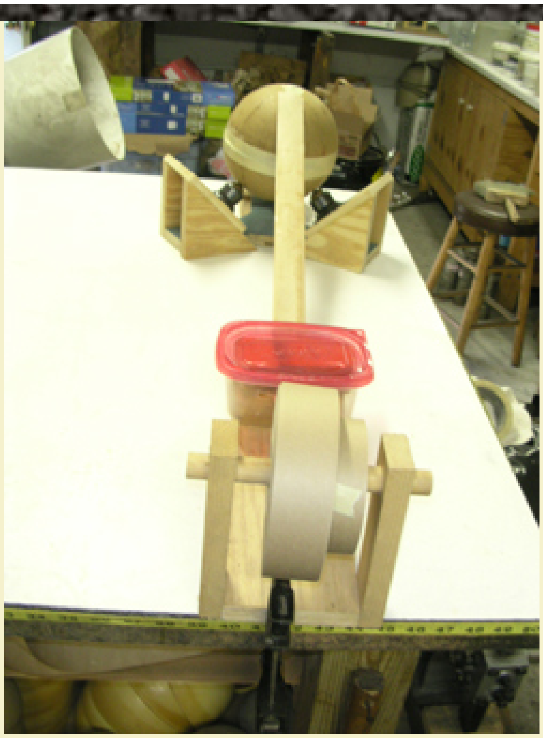

Figure 15: Taping setup with a rollnig jig to aid manipulation of an 8" shell.

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8" Brocade Crysanthemum Shell

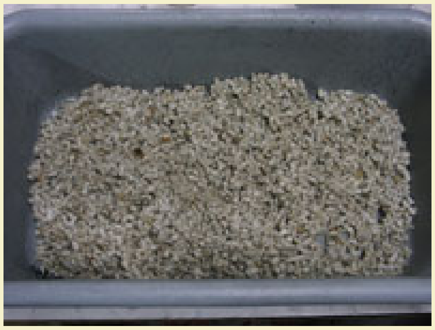
Figure 1: Cotton seeds in a mixing bucket.

Introduction:
As spherical shells increase in size, the internal volume to be filled with burst charge increases by a power of three. However, the amount of powder required to break these larger shells does not increase by a factor of three, thus a way is needed to reduce the amount of actual burst charge while still filling a large volume. This is commonly done by the use of "filler," which is any material that is coated with the burst charge in order to increase its volume without increasing the actual amount of burst charge.

The larger a shell gets, the larger the filler needs to be. While rice hulls work for smaller shells, something with more volume is desireable for bigger shells. This can be seeds, pieces of cork, beans, popped pop corn or any similar sized light weight material that powder can be made to stick to.

For this single petal 8" shell, either cotton seeds or puffed rice cereal are coated with ball milled meal powder to make the burst charge.

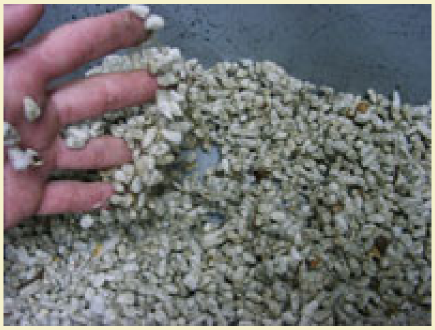
Figure 2: Cotton seeds dampened with water, but not soaked.

Cotton Seed Break Charge:
Cotton seeds make an ideal choice for burst charge filler for larger shells. They are a good size, cheap, light weight and they have a fuzzy coating that easily picks up the meal powder. The only drawback is they are not exactly easy to come by. There are no suppliers that sell them in hobbyist quantities that I know of, which means you have to be resourceful in finding them. This means you have to get on the internet and search for farming companies that sell cotton seeds, then convince one of them to sell or give you a "sample."

While cotton seeds sell at a very low price per pound, the companies that sell them have minimum container sizes that are prohibitively large for the hobbyist. Even a small scale supplier wishing to resell cotton seeds would have a difficult time storing a 40 foot trailer full of cotton seeds, which is a typical minimum order size.

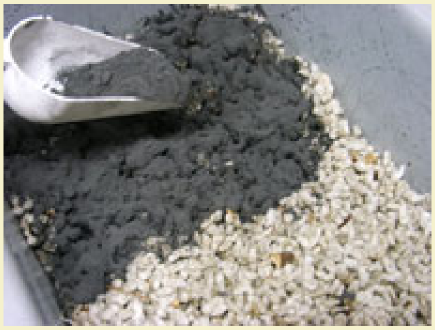
Figure 3: Adding meal powder to the damp seeds.

Obtaining a sample from a supplier may get you 100 pounds of cotton seeds at no cost at all. Cotton seeds can actually go bad in storage by sprouting, which is caused when the seeds have too much moisture. It is important to find out how long the seeds have been stored before getting any large quantity. If your supplier has had them around for a year or more, then you don't have to worry about sprouting. Otherwise you will have to dry your seeds in an oven to remove any moisture.

Coating Cotton Seeds:
There are a few methods I have heard of for coating cotton seeds. One method involves making a meal slurry and then pouring it onto the cotton seeds and stirring it around. Some builders report that this method can result in a big glob of entangled seeds if you are not careful. A similar method with similar complaints involves adding the dry cotton seeds into a tub of meal

slurry.

Because the cotton hairs on the seeds tend to get matted down and entangled with each other, the ideal process allows the seeds to be coated while also keeping them separated. This is better achieved by first wetting the cotton seeds and then introducing dry powder to them and stirring them around.

Figure 1 shows a large plastic bucket filled with dry cotton seeds to be coated. Start by spraying the seeds with water containing 14% alcohol, stirring them as you spray. You don't want to soak the seeds in a bucket of water because then they will be overly soaked and stick together. By spraying them you will be able to control the amount of starting dampness, which will be the point when the cotton is saturated and the seeds just start sticking to the bucket walls and your hands (see Figure 2).

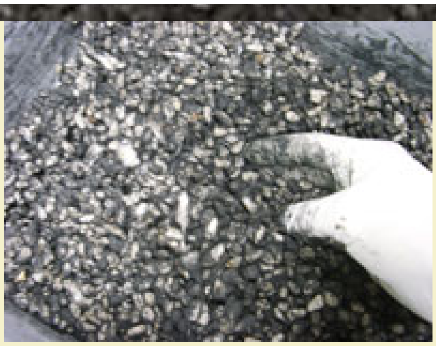
Figure 4: Mixing in the meal by hand.

Once the seeds are dampened, introduce the dry meal powder containing 5% dextrin as shown in Figure 3. Incorporate the powder by stirring with your hands, then keep adding more until the seeds stop picking up the dry powder.

The powder is not added onto the seeds in any particular ratio as it is for other burst charge types. It is added until the seeds are completely covered so that no white spots are visible, as shown in Figure 5. If the seeds stop picking up powder before they are fully coated, it may be necessary to spray them again before adding more powder.

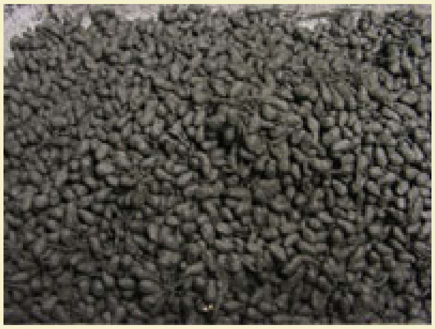
Figure 5: Finished cotton seeds are completely coated with meal.

Another method for coating the seeds is to use a star roller to keep from having to stir them by hand. The seeds are tumbled in the roller and alternately hit with water spray and powder.

Once the seeds are coated, lay them out to dry on sheets of newspaper or screens.

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Making KP Burst Charge

Introduction:
"KP" is the name given to a type of shell burst charge that uses Potassium Perchlorate as the oxidizer in combination with charcoal and sulfur. The KP burst charge was developed in 1955 as an alternative to the chlorate containing H3 charge. While it is not strong enough to replace H3, flash or whistle mix in shells smaller than 4", it makes a great burst charge for shells in the 4" to 6" range. The advantage over H3 is that there are no sensitivity issues when coming into contact with meal primed stars. The bursting strength of KP is also equal to H3, although the burn rate is somewhat slower and varies according to the containment strength of the shell casing. KP is less friction sensitive than H3, flash and whistle mix burst charges, thus making it safer to work with. Every commercial ball shell I have ever dismantled also featured KP burst rolled onto rice hulls, so I guess the Chinese prefer it as well.

The thickness of the KP coating on rice hulls is critical to performance, especially when used on the thin, flakey type of rice hulls available to most hobbyists. The thicker the coating is, the less compressible the resulting burst charge is and the better it will perform (read here to find out why). The football shaped grains of commercial KP hulls found in Chinese shells seem to be rolled on something more like a grain of rice rather than the hull of the rice, which gives a solid, uncompressible grain. Coating the flakey type of rice hulls commonly available in America with a ratio of at least 7:1 KP to hulls will help reduce the compression issue and works well for many mid-size shell configurations.

Rather than stock many different ratios of KP hulls, I tend to design a range of burst configurations for shells that work using just the 7:1 charge (see configurations at end of article). This allows me to make single large batches of just this one charge rather than several smaller batches of various ratios. In the cases where the charge is too strong for the given volume to be filled, I simply cut it with BP puffed rice or color stars. Trying to cut the burst strength by lowering the charge ratio will increase the compressibility of the charge, and also result in uncoated bare spots on your hulls that will reduce the rate of flame propagation. You can actually build any type of ball shell from 4" all the way up to 12" using nothing but various combinations of 7:1 KP hulls and 4:1 BP puffed rice. The bigger the shell gets, the more the BP charge replaces the KP charge and vice versa.

Figure 1: 500 grams of dry hulls ready for making KP charges

Mixing the KP:
The formula for KP burst charge given by Shimizu calls for 70% Potassium Perchlorate, 18% charcoal, 12% sulfur and +2% glutinous rice starch (can be replaced with +5% dextrin). However, using the standard 75/15/10 formula for black powder works just as well and is what I typically use. I like to mill my charcoal and sulfur together in a 3:2 ratio, then store this pre-milled C/S mix for later use when making both BP and KP. This way I can mix one part C/S with three parts of the appropriate oxidizer for the final mixing, be it perchlorate for KP or nitrate for BP. The table below shows the amounts to mix for

rolling.

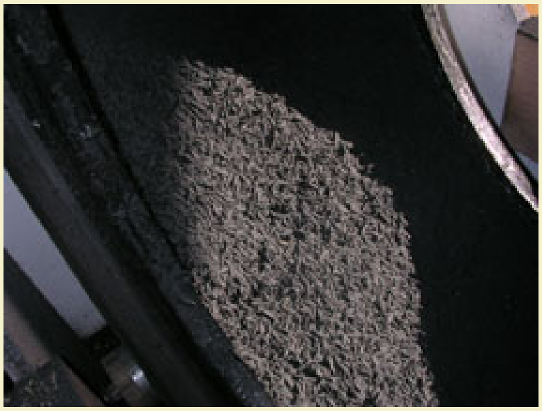

Figure 2: 3500 grams of KP rolled onto the hulls.

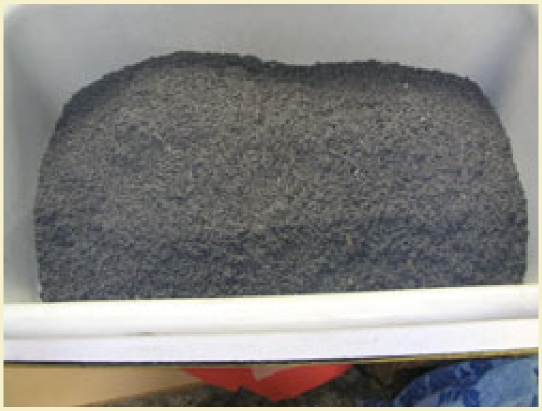

Figure 3: Resulting hulls ready for drying.

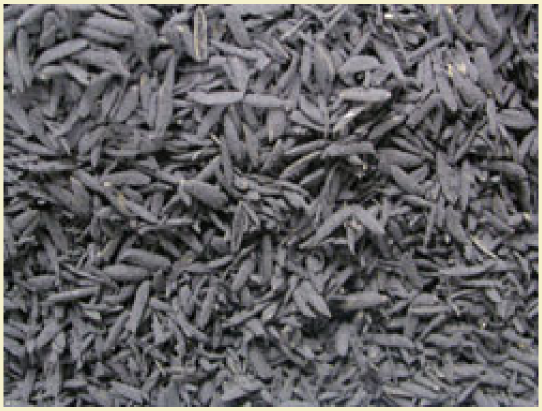

Figure 4: Closeup shows clean, unclumped hulls that flow easily even when wet.

milling the C/S with a typical 6" dia x 8" long milling jar (or equivalent volume).

C/S Pre-mix (light charcoal)

Home Made Charcoal	**300 g**
Sulfur	**200 g**

C/S Pre-mix (dense charcoal)

Commercial Airfloat Charcoal	**360 g**
Sulfur	**240 g**

Because home made charcoal tends to be more fluffy than commercial charcoal, smaller amounts must be used to properly charge the mill jar compared with the denser charcoal. The type of charcoal used is not as important to performance when making KP the way it is when making BP. Fancy charcoals like willow or paulownia are simply not necessary here, as the commercial airfloat will work just fine.

Potassium perchlorate is certainly less sensitive than its chlorate brother, but still too sensitive to safely process in a ball mill. For this reason the perc must be screened together with the C/S mix by hand.

Final Mix (screened by hand 3 or 4 passes)

Potassium Perchlorate	**2500 g**
C/S Mix	**833 g**
Dextrin	**167 g**

This will give you 3500 grams of KP, which will then be rolled onto 500 grams of rice hulls to give the desired 7:1 ratio. These numbers were arrived at by working backwards from the largest batch of rice hulls that my rolling tire can process, which is about 500 grams of dry hulls.

Rolling the Hulls:
For reasons explained here, using a star roller to apply burst charges to rice hulls or any other type of core is the best method to use. Initially I thought the NASCAR tire roller would not work well for doing this, but after some experimentation it turns out a tire roller is actually capable of performing this task.

Figure 1 shows the tire roller charged with 500 grams of rice hulls. Unfortunately the light weight of rice hulls causes them to slide in place once the roller is started, rather than form a tumbling pile the way stars do. This tends to make getting the process started a bit of a pain, since you have to manually tumble the pile by hand until they are coated enough to tumble on their own. This is done by continually scooping hulls from the top of the pile so that they cascade down the slope after applying each powder increment. It is important to continually tumble the pile by hand in this way during the early stages of rolling.

One key to rolling rice hull charges is to use plenty of water between powder increments. There is a natural tendency to add powder and water in the same way you would for rolling round stars, but this process actually requires much more water between powder increments than star rolling does. If it looks like the powder is not sticking to your hulls, then you are not spraying them enough. A paint sprayer or weed sprayer filled with water can actually help reduce the fatigue of continually pumping a spray bottle during this process. Paint sprayers driven by an air compressor must have the pressure turned down below 10 psi however, otherwise the air blowing out the nozzle will blow your hulls and powder all over the place.

Once your powder bucket is about half empty, the hulls will begin tumbling more on their own. At this point the process becomes much easier, freeing up both hands to do the spraying and powder scooping.

As your powder bucket starts getting close to empty, stop adding water to the hulls and just add powder. Allow more time between powder increments so that the hulls can pick up the dry powder before adding more. As in star rolling, this final step helps to "dry out" the material so that it will flow easier and dry faster.

Once all your powder has been rolled onto the hulls, use a milk jug scoop to remove the hulls while the roller continues to run. The hulls should be smooth and flow easily without sticking to anything. The hulls should be dried on drying screens lined with newspaper to help draw moisture out of the hulls. The dry-box shown here is capable of drying a batch of hulls this size in just one day!

Figure 3 shows the finished hulls, which is enough to fill two one gallon containers and last the typical hobbyist a year or more.

Recommended Uses:

4" single petal
5" single or double petal
6" double petal
6" single petal w/pistil (pistil stars mixed 50/50 with

the KP burst)
6" single petal (4:1 BP puffed rice mixed 50/50 with the KP burst)

NOTE: All shells noted are paper ball shells. Not recommended for plastic ball shells, canisters and especially multi-break canisters.

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Tool Tip...

Coating Rice Hulls in a Star Roller

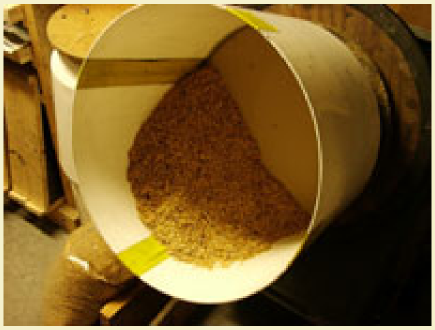

Figure 1: Roller filled with rice hulls.

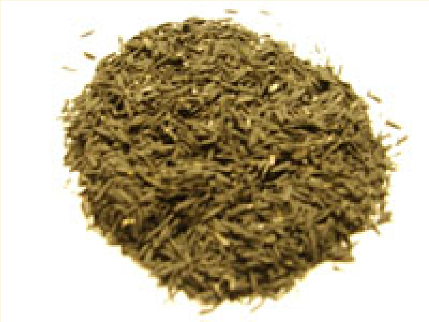

Figure 2: Hulls coated with a 6:1 ratio.

The commonly described method of coating rice hulls with a burst charge, which involves pre-soaking the hulls with water prior to tumbling them in a pan while adding powder, is not well suited to producing high charge-to-hull ratios and often results in clumping, excessive dust and longer dry times. Draining the water from the hulls can present a problem, as failing to drain enough water from the hulls will result in overly damp hulls that easily clump together when the powder is added.

The quickest and most effective way to coat rice hulls involves a tool you may already have: a star roller! Since star rollers are designed specifically for applying powder to a mass of tumbling cores, it is ideally suited for coating rice hulls. There is no limit to the amount of powder you can pack on to the hulls in this manner, and since the hulls are not soaked to the core with water, the finished hulls will dry faster. The fact that the water and powder are alternated in layers helps keep the coating smooth with little or no crumbly dust in the finished product.

Start by weighing out an amount of hulls that almost fill the capacity of your star roller, as shown in Figure 1. The amount of powder required to give the hulls the proper ratio is also weighed out and kept in a bucket nearby. Start the machine rolling and spray the hulls with water until they reach a point where they start clumping together. Use your free hand to stir the mass of hulls, bringing the inside hulls to the top while spraying.

Once the hulls are starting to clump together, just start dumping powder on them. It is much easier coating hulls than rolling stars, since they are not as fragile and it doesn't matter if a few of them stick together. When powder gets stuck to the sides of the roller, just use a handful of hulls to clean the sides. It helps to churn the pile of hulls with your free hand frequently, breaking up clumps when they do occur.

Simply alternate spraying the hulls till they clump and adding powder till they flow nicely. When you are getting near the end of your powder supply, stop the spraying and apply an overdose of powder. Walk away from the machine and let the excess powder slowly pick up as it wicks the moisture out of the damp hulls. This trick reduces the dry time as well as the chances of the hulls being overly damp when you run out of powder.

Once dry, your hulls should look clean and separated like Figure 2. Hulls dried in a dry-box may be ready for use the same day they were rolled!

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Technique...

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Round Shell Pasting Methods

by Kyle Kepley

Introduction:
The process of applying pasted strips of paper to a round shell is probably the most tedious and dreaded aspects of making paper round shells. When compared to the quick results obtained from gluing together a set of plastic hemispheres, it is not hard to see why most people choose to make plastic ball shells instead.

However, the superior strength of paper over plastic gives the burst excellent containment, which allows a variety of break charges to be used successfully. Paper ball shells do not have to be broke as hard as plastic shells in order to get a nice round break. Thus, it is easier to dial in a break charge with a paper shell, making blind stars less of a problem. Some builders choose a hybrid approach of building plastic shells and then strengthening them with a few layers of pasted paper. This requires less layers of paper and thus saves time.

There are some cases where plastic simply can not be used, such as shoot sites where plastic fallout is not allowed. The use of plastic shells as inserts inside of larger shells also can cause problems, as the extreme heat and pressure of a large shell break will melt and crush plastic inserts in the brief instant before the shell opens.

Note that break charges specified for plastic and paper shells are not interchangeable. A break charge that works in a plastic shell can not be used in a paper shell or the stars will likely be blown blind. Likewise, a break charge specified for a paper shell will produce a poor break in a plastic shell.

The average mid sized ball shell requires about an hour to paste correctly regardless of the method used. Trying to save time by using wider strips of paper, applying fewer layers or using thicker paper usually gives inferior results.

For more information on how to determine the number of layers to paste for a given shell size, as well as how to calculate the number of strips required to finish a shell of any diameter, see this month's Design Notes section.

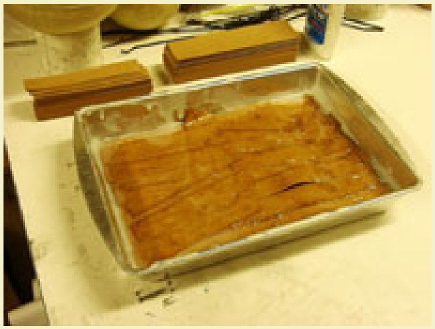

Figure 1: Soaking strips in paste pan.

Preparing the Strips
All the methods of ball shell pasting illustrated in this article require paper strips in some format. Regardless of which method you use, all strips of paper must be cut prior to pasting, soaked in paste, broken in and then applied to the shell one at a time.

While each strip could be pasted and broken in one at a time, such a procedure would make an already time consuming process even more time consuming. The fastest way to get all the strips pasted and broken in is to break them all at once.

A flat pan is filled with about three cups of thin paste, or more depending on what size shell you are making. All the strips are then submerged into the paste one at a time so that both sides of

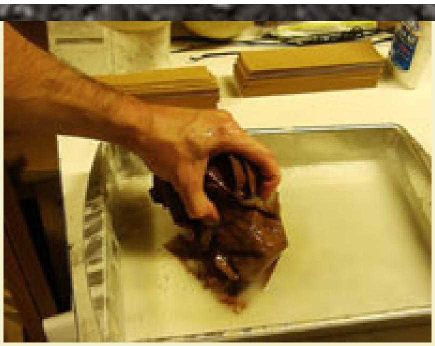

Figure 2: Breaking in the strips.

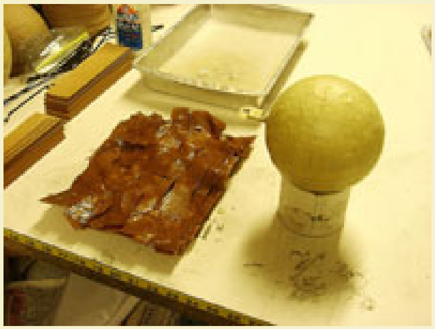

Figure 3: Ready to apply.

each strip come into contact with the paste. Simply dumping all strips into the paste at once would result in dry spots between some strips. Thus it is necessary to submerge one strip at a time, spreading them into a layer that fills the entire pan as you go. The strips are easier to remove from the pan if each new layer runs perpendicular to the layer beneath it. When the pan is filled it should look like Figure 1.

The mat of pasted strips can now be crumpled up into a ball and squeezed in order to break the paper. The color of the strips should turn to a darker brown as the paper becomes saturated with paste, as seen in Figure 2. Kneed the paste into the paper by crushing it into the pan from different angles.

Once the paper is thoroughly impregnated with paste, flatten it back out onto your work table so that the strips may easily be removed from the stack.

One traditional method of preparing pasted strips for oriental ball shells, as documented by Shimizu in Fireworks, the Art, Science and Technique, does not involve breaking the paper. The paste is applied to only one side of a full sheet of paper, then quickly cut into strips using a large paper cutter. In this case the paste used does not contain much water in order to keep the paper from becoming too mushy to cut. Since the paper will not be as pliable as strips that are soaked in paste and broken in, the paper must be thinner than usual so that they will lay flat against the shell. Thinner paper requires that more layers be applied to obtain the necessary thickness.

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Ball Shell Pasting Methods...

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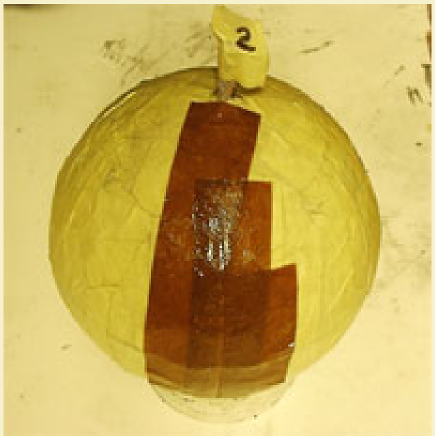

Figure 4: The 3-strip pattern.

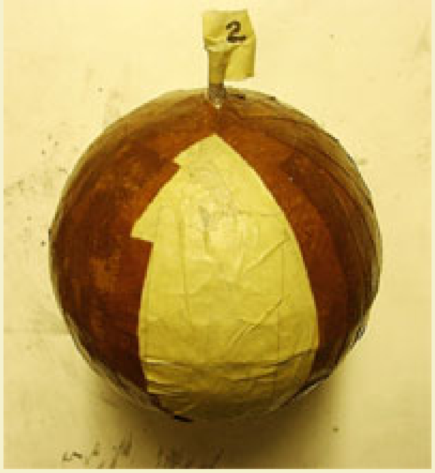

Figure 5: Working the pattern around the shell.

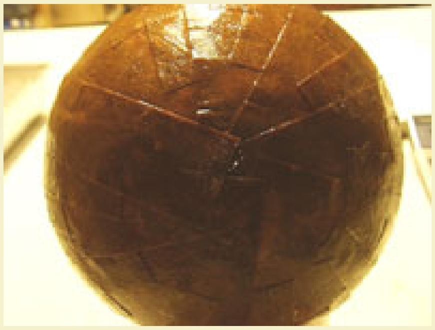

Figure 6: End view of strip pattern.

The Three Strip Method:

This pasting method was adapted from Westech technical paper L-603 by Ralph Degn. It is my own preference due to the fact that the strips are easy to prepare (no special shapes), they are all the same size, each layer maintains the same orientation and the position of the strips can be adjusted as necessary to keep the shell perfectly round.

The width of the strips are approximately 1/16th of the circumference of the shell O.D., and the length is 1/3 the circumference. Using these dimensions, it will take roughly 30 strips to complete one time around the shell, which is actually two layers of paper due to the fact that each strip overlaps by half the width. The weight of the paper can be up to 70lb for 6" shells and larger, but a lighter weight must be used as the shell diameter decreases. The curvature of smaller shells does not permit thicker paper to lay down flat when pasted.

Begin by placing a flag of masking tape over the exposed time fuse in order to protect it from the paste. This flag can also be used to keep track of your starting position for the first strip so that you know when you have completed a layer. The shell is easier to work with if it is resting on a tubular stand to keep it from rolling around. PVC couplings work good for this purpose.

The strips are applied in a three strip pattern that repeats as you progress around the shell. The first strip starts from the time fuse, the second strip is centered directly in the middle of the shell, and the third strip ends on the pole opposite the time fuse. Each strip overlaps the one before it by half the width at the equator of the shell. The overlap will be slightly more toward the two poles.

This three-strip pattern eliminates the pileup of overlapping paper that would occur at each pole if full length strips were used. If the shell does begin to take on a slight egg shape during pasting, the first and third strips of the pattern can be shifted toward the middle of the shell, which reduces the overlap at both ends.

Each new layer is pasted over the previous layer in exactly the same way. There is no need to orient successive layers in different directions, which eliminates the need to even keep track of layers so long as you know how many strips are required to complete the necessary number of layers and have only prepared that many strips.

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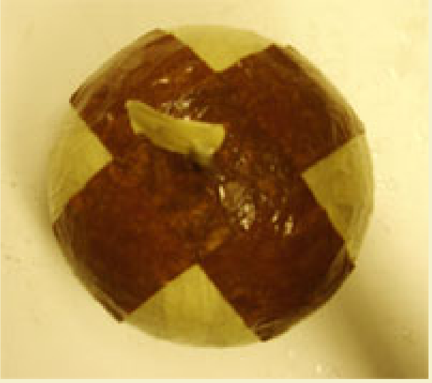

Figure 7: First three strips in place.

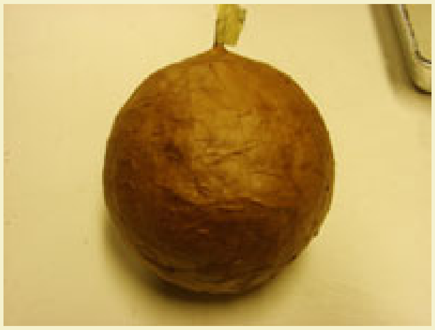

Figure 8: Thick paper results in lumpy shell.

The Shimizu Method:

This pattern of strip placement is described by Shimizu on page 250 of Fireworks, the Art, Science and Technique. The strips are quite wide, being 1/8th the circumference of the shell, and three different lengths are required for each layer.

Only seven strips are required for each layer, making this one of the fastest pasting methods. However, since there is no overlapping of paper, it will take the application of two full layers (14 strips) to equal one layer of the 3-strip or tapered strip methods. In addition, more time is spent flattening the paper down due to its excessive width. Shimizu states that the shell should be rolled with a rolling board to help flatten out the wrinkles, and that only one layer should be applied at a time between drying.

While drying each layer one at a time may work in a production environment where many shells are being made in parallel, it is impractical and unnecessary for the hobbyist to follow this procedure. It is more common for the amateur builder to apply half the layers on a 5" or 6" shell, dry the shell, then apply the other half. Larger shells require more paste/dry sessions as the diameter increases. Applying too much paper all at once can cause the shell to become mushy and result in a flat spot where it is resting while drying.

For this wide strip method, the grain of the paper should run parallel to the width of the strips. Because these strips are so wide, the paper needs to be thinner than other pasting methods so that the paper will lay down with minimal wrinkles. The shell pictured in Figure 8 was a 6" pasted using 70lb virgin kraft, which resulted a rather pruneish look when finished. Despite the deformed surface, the shell still broke symmetrically.

The first strip is the longest and wraps all the way around the shell, starting and ending at the time fuse. The second two strips are less than half this length, as they run at right angles to the first strip from top to bottom. The second and third strips should not overlap the first strip by much. The last four strips will fill in the remaining quadrants shown in Figure 7. They should be long enough to just cover the unpasted area with a minimal of overlap.

One defect in this pattern is that there is an asymmetrical overlapping of paper towards the two ends of the shell, which can result in a slight oblong shape after many layers are applied. One technique to try and avoid thick spots is to alternate the orientation of each successive layer so that the thick spots are distributed evenly across the shell. This method also helps mix up the grain direction, giving the shell a more even tensile strength. This is similar to how plywood is made stronger by having the grain run in opposing directions for each layer. Even if the pattern was only alternated between the three perpendicular axes the results would still be improved.

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The Tapered Strip Method:

The tapered strip method is probably one of the most simple pasting methods to apply. Thin strips, with a width of about 1/16th of the shell circumference and a length of 1/2 the circumference, are tapered at each end as shown in Figure 9. The taper reduces the excessive overlap that occurs at the poles of the shell, preventing the shell from becoming egg shaped. Since the paper becomes quite thin at each end, it is necessary to use virgin kraft to keep from having problems with the paper tearing during the pasting and breaking process.

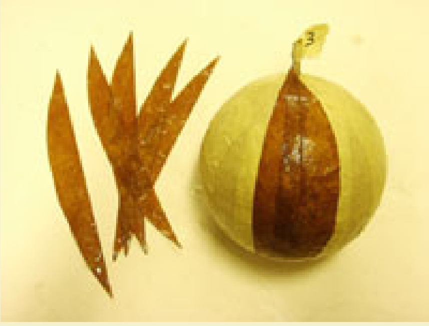
Figure 9: Full length tapered strips.

The first layer is applied by running the strips from the time fuse down the side of the shell perpendicular to the seam. Each strip overlaps the previous strip by one half the width, making one complete round equal to two layers of paper. Successive layers should be rotated in order to alternate the grain direction of the paper as well as to prevent a weak spot from forming where the ends of all the strips meet. Since the tensile strength of the paper is stronger in the direction that the grain runs, having the grain run in different directions for each layer should create a more uniform resistance to pressure in all directions.

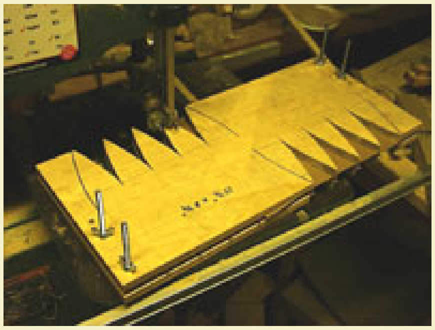
Figure 10: Cutting patterns on 100 sheets at once with a band saw jig.

Commercial manufacturers often use this method as the final finish layer on their shells, since it has the cleanest appearance. Some manufactures (Lidu for example) use this method for all layers, pasting each layer in a different orientation as mentioned above.

One drawback to this method is the time spent cutting the strips to the proper shape, as well as the wasted paper that results. The cutting process can be made faster by cutting stacks of paper on a band saw with a wooden template jig as shown in Figure 10. A stack of paper is sandwiched between two plywood templates, which are clamped via bolts that keep the paper from shifting during cutting. Over 100 sheets can easily be cut at one time this way, although a template jig must be constructed for each size shell you plan to make. Once the stack of paper has been cut, the strips are made by cutting them from the patterns as shown in Figure 11.

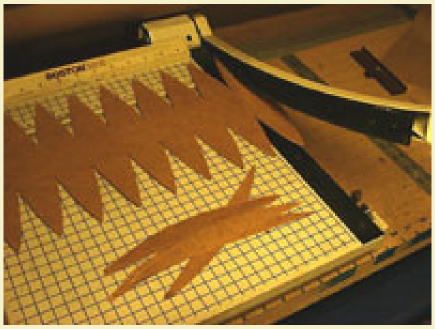
Figure 11: Cutting strips from pattern sheets to obtain tapered strips.

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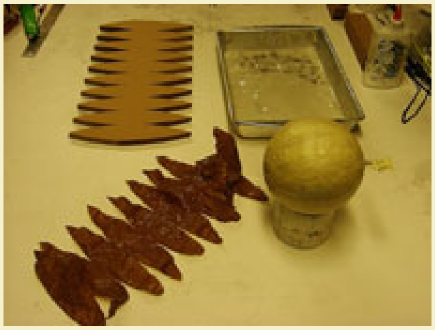

Figure 12: Pattern sheets pasted and ready to apply.

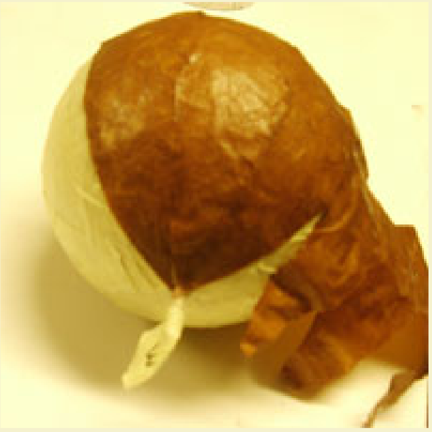

Figure 13: Rolling on a pattern sheet.

The Globe Pattern Method:

This method is of my own creation and was inspired by the patterns used to wrap paper maps of the Earth onto spinning globes. The maps are created using the same jig pictured in Figure 10, only they are used as one large strip that is rolled around the shell and pleated down. The length of the strip is obviously equal to the circumference of the shell, and the width is equal to one half the circumference.

The pattern is calculated using this calculator, which prints out a set of data points that must be graphed to scale on a piece of cardboard. This will give you one half of one gore (gore refers to one of a number of tapered 2D strips that are used to create a curved 3D surface). The pattern is then traced over and over, side by side, until you have the number of gores that you specified when you ran the calculator.

The fewer gores you use, the easier it will be to make the patterns. On the other hand, large gores will not lay flat on the shell without wrinkling. I find that at least 10 gores is necessary for a mid sized shell.

Each pattern sheet will count as one layer of paper, since there is very little or no overlap. Like the tapered strip method, each successive pattern sheet should be applied in a different direction than the previous sheets. This will mix up the grain direction and prevent any weak spots.

The obvious drawback to this method is the necessity to fabricate the special pattern sheets. This method can also result in a lumpy shell unless thinner paper is used and/or the number of gores is 12 or more.

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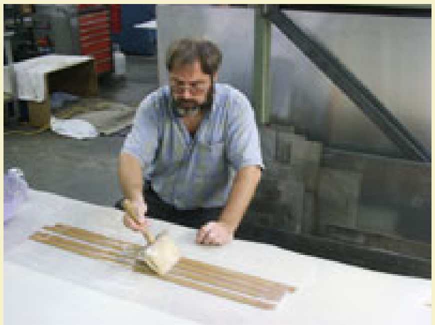
Figure 14: Applying paste to stacks of full-length strips.

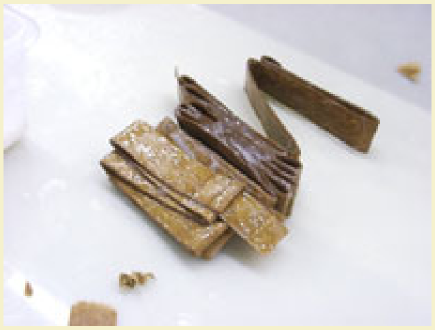
Figure 15: Breaking the paper.

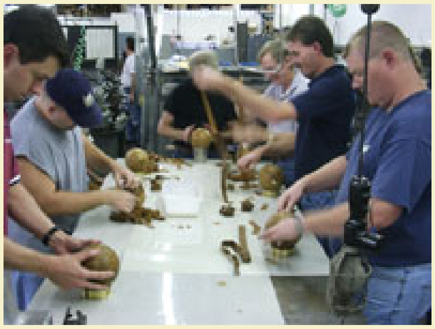
Figure 16: A shell pasting assembly line.

The Assembly Line Method:
Like most things in manufacturing, techniques change when mass production is required. Having many workers available to paste many round shells in one session allows techniques to be used that will decrease the overall production time for each shell. The technique described here may be used when groups of friends or guild members pool their labor together for making a lot of shells at once.

First a large quantity of paste is prepared using a blender to make the mixing go faster. A five gallon bucket of paste will do about 50 shells. Small pans of paste are distributed to each table where pasting will be done, which will be used to prime the dry shells and rewet strips when necessary. The remainder is placed at the strip pasting station.

Two people are dedicated to pasting and breaking the strips of paper. This process involves laying out several 36" lengths of 3/4" wide virgin kraft strips in parallel, then brushing paste onto them using a large brush (see Figure 14). Once a thick layer of paste covers all the strips, another layer of strips are placed directly over them, only offset from one end in a stair-step fashion. Not placing the strips directly over each other allows them to be pulled apart easier. Paste is again applied to the new layer of dry strips, then more successive layers are stacked on top until they are about six layers thick. The stacks of strips are then folded up like accordions and squished back and forth in order to break the paper. The resulting wads, shown in Figure 15, are then left to sit so the paper soaks up the paste and becomes softer. When the color of the paper has changed to a dark brown, then the strips are ready for application. When done correctly, there should be no dry spots on the strips when they are pulled apart.

About ten pasting stations will keep pace with the two people making the pasted strips. Figure 16 shows the pasting operation underway. The loaded shells are supported on cylindrical collars to keep them from rolling around during pasting. The dry shell is initially primed with a layer of paste before applying any strips. The long strips are torn to the desired size as they are applied to the shell, which eliminates the need to cut strips to size prior to pasting and breaking the paper. When production involves the same task repeated hundreds of times such as this one, even small amounts of time saved by removing unnecessary steps can multiply into a considerable amount of time shaved off the process as a whole.

A pasting pattern of one long strip and one short strip is applied such that each strip overlaps the previous by half it's width. Thus, one full application of strips equals two effective layers of paper. The long strip reaches half the circumference of the shell, while the shorter strip falls a few inches short of each end. The shorter strip helps eliminate excessive overlapping of paper at the end points, which can make the shell oblong and possibly prevent it from fitting in the mortar. The long strips should not overlap each other at the ends or large lumps will form. The pattern of one long strip followed by a short strip is continued until one full layer has been applied.

After each paste layer is completed, the shells are placed on a drying table with a fan blowing air across them, as seen in Figure 17. By the time one layer had been applied to all the shells, the first ones completed are dry on the surface. Shells were are then removed in order of dryness and another paste layer is applied. In order to keep the shells from getting mixed up, two tables are used. One table holds shells with x number of layers, while the second table holds shells with x+1 layers. When all shells have progressed from the x table to the x+1 table, then the next layer is ready to be applied.

Because the shells are continuously being dried as they are being pasted, all six layers can be applied in one session without the need to force dry the shells when they are finished. Only an hour after the last layer is applied, the completed shells will be dry to the touch and can be rolled out to smooth them down.

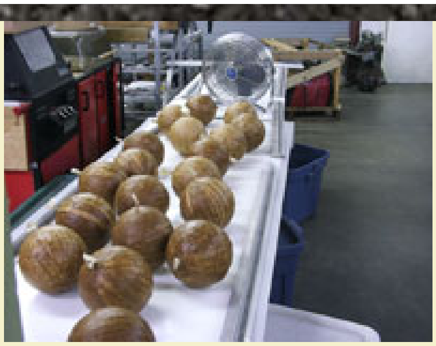

Figure 17: Drying tables.

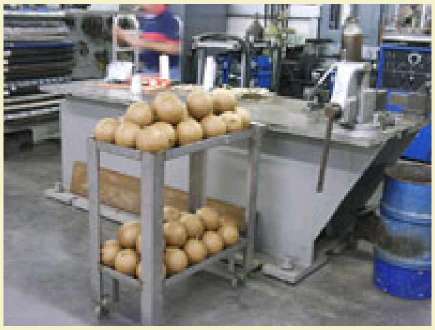

Figure 18: 30 finished shells produced in about five hours.

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Final Notes:
Regardless of which method I use, I prefer to paste all the layers required at once and then force dry the shell using a fan or a drying chamber. This seems to produce a stronger and denser shell when dry, as compared to pasting only a few layers at a time and drying them in between. It is important to accelerate the drying of the shell if all layers are being applied at once, especially if water sensitive hemispheres such as the vacu-form type are being used. Long dry times can cause water to leech into home-made hemispheres, soften them and then deform the shell upon drying.

While shells can not become driven in the way stars can, it does take longer for them to dry when many layers are applied at once. If layers were applied one at a time and fully dried before the next layer was applied, the way Shimizu describes, the shell can actually be ready to shoot sooner than if all layers were pasted at once and then dried. This is a rather inefficient way of building just a single shell, but works well when building many shells together as a group.

Having made many paper round shells, I have tried everything I can think of to shorten the time required for pasting. But regardless of which method I've used, it's difficult to get the time down below 4 minutes per layer (includes the time spent pasting and breaking the paper). There are some ingenious builders who have built machines for automating the paste process, usually involving the use of gummed paper tape being spooled off a large roll onto the shell, which is rotated slowly in a cradle. Unfortunately, building such machines is beyond the abilities of the average hobbyist.

Some time can be saved by purchasing your paper pre-cut into strips of the desired width, such as those sold at pyrosupplies.com. I've been using the PyroSupply strips for over a year, and find the quality and wet-strength of the paper is ideally suited for making ball shells.

The bottom line is if you want to shoot paper, you have to do the time!

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Strip Pasting Calculations
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Technique... **Page 1**

Rolling Core-less Microstars

Introduction:
Microstars are tiny stars generally less than 1/8" in diameter which are employed in special effects such as gerbs, matrix comets, very small shells, indoor sky-burst effects and other uses where small, brief colored sparks are desired. Because the stars are so small, rolling them using a central core of inert material would consume too much relative volume and drastically reduce the burn time of the star. Thus the most effective microstars should be made from solid composition with no core.

Because of the core-less requirement, the star roller would not seem to be an option for making microstars. However, upon dissecting some small round stars found in Chinese consumer products, it can be seen that they do have a process for rolling round stars without using cores.

When rolling round stars in a machine, small stars often form from bits of composition or other debris and grow into round stars without ever starting from a core. While this is undesirable when making normal stars, it would be nice to have the ability to create these small stars in a controlled manner instead of getting them as a byproduct. The process described in this article describes how to do just that, and gives a useful range of microstars with little or no dust product and only minimal amounts of oversized stars.

I have heard about people making microstars by screening damp composition into a star rolling bucket as it was rotating, but I never tried this due to the difficulty of holding a screen in one hand while pushing comp through it with the other hand. But with the large diameter and bottomless design of the NASCAR tire roller, it is possible to easily mount a screen in the center of the tire so that you don't have to hold it while working. The result is very easy way to make core-less microstars in sizes ranging from a grain of sand up to full sized round stars. If you are contemplating trying the NASCAR roller for yourself, here is yet another incentive!

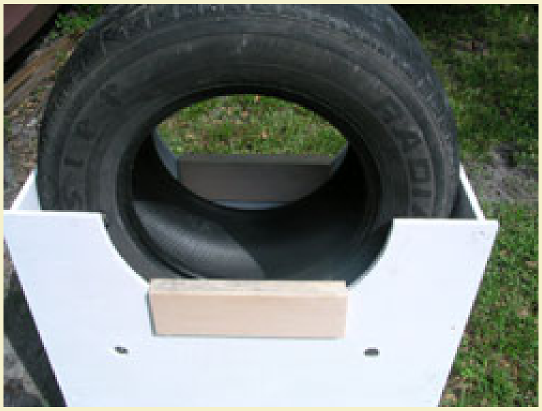

Figure 1: NASCAR star roller modified for holding a central screen.

Setup:
Before this method can be used, the NASCAR star roller cabinet must be modified slightly from its original design. Figure 1 shows some wood blocks attached to the front and back panels, which give a flat surface for resting the screen. The construction plans for the circular cutout should really be modified so that the panel is flat in this area, thus eliminating the need for the blocks. If you have not built one of these yet and plan to, then be sure not to cut the full half circle, rather leave a flat spot so that these support blocks are not required.

Next you will need to build a screen or modify an existing screen so that it can rest between the blocks. The screen should be about 15 mesh, and window screen can be used also. Figure 2 shows the screen made specifically to sit on top of the two

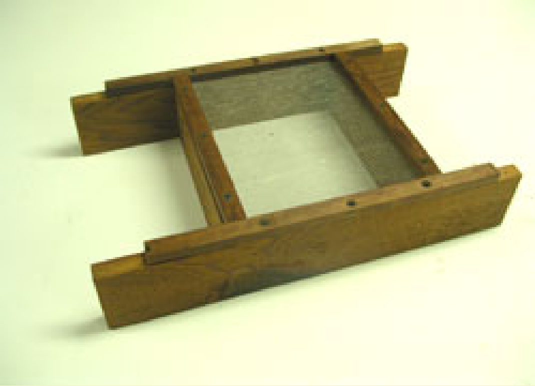

Figure 2: A 15 mesh screen built to mount inside the NASCAR roller.

blocks. Note that the hold-down clamps on the sides fall short of the ends, which creates a notch to lock in place between the support blocks. This prevents the screen from sliding while you are pushing comp through it. The height of the screen walls really should not exceed 2 inches, otherwise it can be hard to place your palm flat on the screen while working.

The exact dimensions of this screen will depend on the tire you are using. I have since upgraded the tire I use to a Hoosier Radial GT, P275/60R15, which has a 27" Diameter and a 10" wide rolling trough. This has more volume for rolling than my original tire mentioned in the construction notes, and the inside surface is smoother between the ribs. It also has a wider opening measuring 7-3/4" across, which is ideal for using this screen technique. The screen can not exceed the width of the tire opening, thus the wider your tire opening is then the larger the screen area you will have to work with. The width of the screen should be as wide as you can make it without contacting the tire during use. If the tire does bump it during use, the screen will only center itself with no major disruptions. Allow for some slight wobble in the tire when designing the screen width.

Composition:

First let me say that not all star compositions will work well with this method. Particularly troublesome are the metallic compositions that have a lot of magnalium and parlon in them. These mixtures take an excessive amount of moisture to dampen to the correct working consistency, and even then they are still crumbly and hard to work with. The excessive moisture results in overly wet stars that stick together and clump into larger star clusters once screened into the tire. I'm not saying that it is impossible, it's just difficult and should not be tried until you get good at the easier compositions.

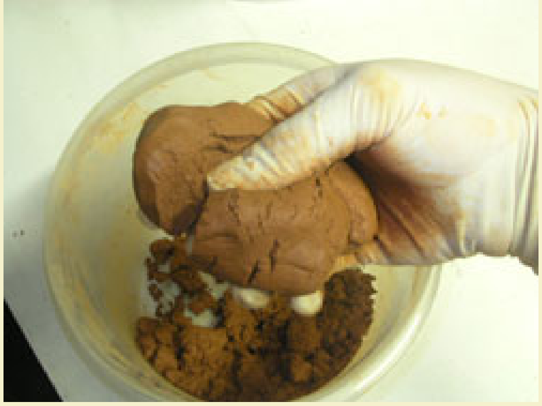

Figure 3: Over wetted composition with a clay like consistency will not work.

The ideal star formulas for this process will dampen to a clay like consistency when wet, such as most organic formulas and other formulas where all the ingredients are finely ground. The formulas that work well for making cut stars are the same ones that will work well for screening core-less round stars.

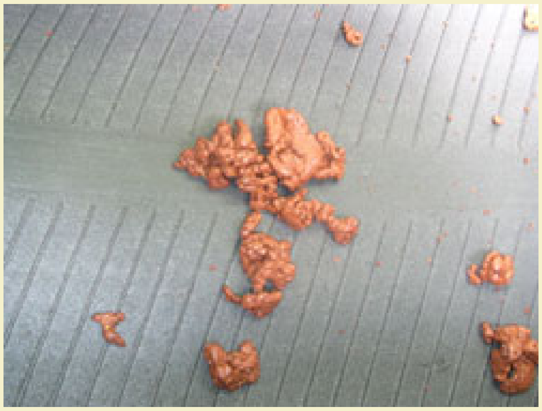

Figure 4: Clumped up mess resulting from over wetted composition (15% water).

Because we are making microstars, it is also desirable to have the slowest burning color compositions possible. I like to use lance formulas for making these, with AP formulas producing the best results in both color purity as well as slower burn rate.

Since AP is more difficult to get these days, this example uses Lancaster's KP based organic red lance formula with 5% dextin added as the binder:

Potassium Perchlorate	**70**
Strontium Carbonate	**18**
Red Gum	**12**
Dextrin	**5**

You will need to prepare about 1/3 the weight of the stars you are making as dry powder, with the remaining 2/3 being dampened with water. The amount of water used to dampen the powder is very critical for this process to work, and you will need to experiment to find the right amount when using other formulas. For the formula above, 13% is the magic number. Deviating by even 1% can cause bad results, although starting 1% too dry is easier to correct than starting 1% too wet. If the mixture can be squeezed into a ball and does not crumble when pushing your thumb into it, then it is too wet. Figure 3 shows the clay like consistency that 15% water will give you with the above formula, and Figure 4 shows the mess that results if you try to make stars with it. The tiny stars quickly stick to each other once they enter the tire, and small clumps turn into bigger clumps and then even bigger clumps. The composition should still be somewhat crumbly when gripped into a ball and then broken apart.

One general rule is that if you have a hard time pushing the composition through the screen because it is getting stuck in the screen, then it is too wet. If the stars develop a wet sheen while rolling, then they are too wet. If the powder easily falls through the screen and you get very fine microstars or just plain dust in the roller, then the composition is too dry. There is an exact point between these two conditions where the microstars will be produced without effort.

Once the proper moisture content has been determined (and recorded for future reference), you must keep a lid on the container during rolling or evaporation will throw off your fine tuned dampness.

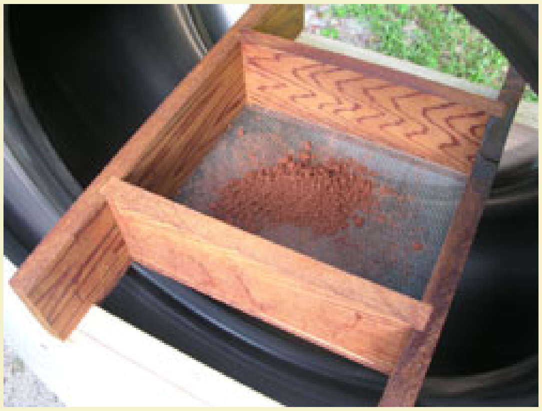

Figure 5: Pushing damp composition through the screen and into the spinning tire.

Rolling:
With the screen in place as seen in Figure 5, start the roller and push a single handful of damp comp through the screen. Check the rolling characteristics of the tiny stars that should result in the tire. If they seem to be clumping together, add some dry star comp to see if they break up. Overly wet stars can not be separated in this way and you will have to scoop them out, add them back to the damp comp and let some water evaporate before continuing. If the stars seem very small or flowing like a pile of powder, spray with some water+20% alcohol to help them clump into stars and pick up dry dust.

At this point you can roll these cores as normal stars

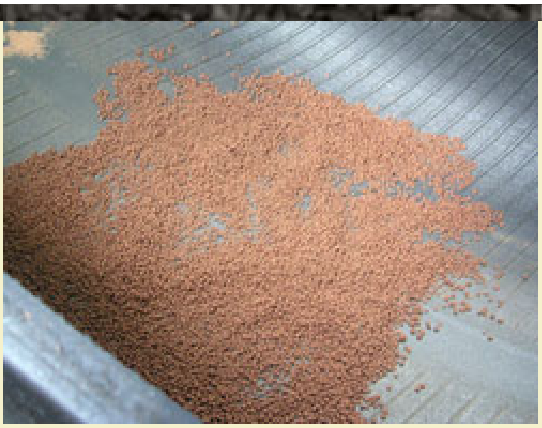

Figure 6: Closeup of microstars ready for removal.

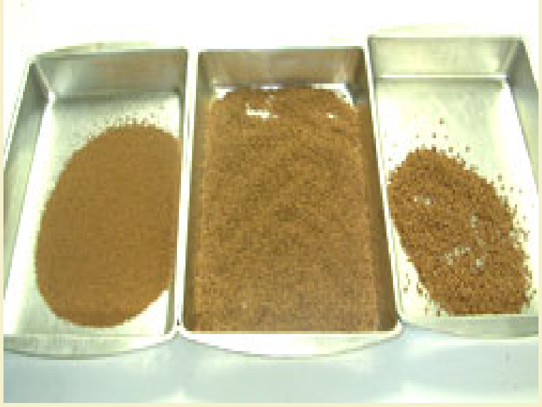

Figure 7: Microstar yield divided into three size ranges.

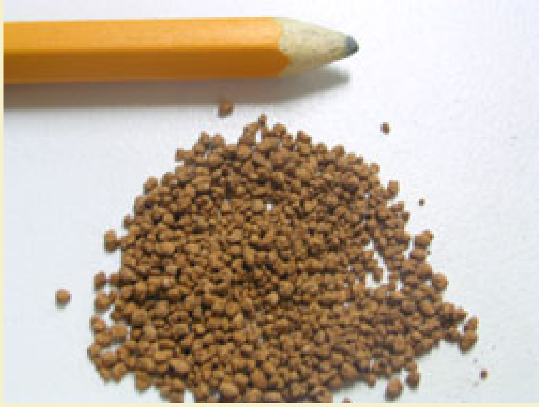

Figure 8: 31% passed through a 15 mesh screen.

by alternating between spraying and adding composition. Since microstars are small, you won't need to do much before removing the stars. The stars are not exactly round at this small stage, since many of them are clusters of several tiny stars stuck together. As the stars get larger they do start to round out, but a screening is necessary to remove some of the unwanted oversized and undersized stars if you want to keep rolling to make normal round stars.

It is better to only process one or two handfuls of composition through the screen before removing the stars, since clumping problems tend to increase when more stars are rolling at once. Doing small batches also limits damage if you mess up a batch by over wetting with the sprayer. Figure 6 shows a batch of microstars ready for removal, which are scooped out with a cut-off milk jug while the roller is running.

The moisture content of your damp powder will also determine the average size of your microstars. Powder on the dry side will produce smaller stars, while damper powder will product larger stars due to more clusters being formed.

The size breakdown of stars created from one kilo of the Lancaster red can be seen in Figure 7 through 10. A 15 mesh screen was used to filter out the smallest stars, which made up 31% of the overall batch weight. These very tiny stars would be good for indoor air burst effects or small matrix comets. If this were a crackle formula then these would make ideal dragon eggs.

The stars that didn't go through the 15 mesh were run through an 8 mesh (1/8" hardware screen) to produce the stars shown in Figure 9. This was the largest output, making up 55% of the total batch size. These stars would also be good for air bursts, small shells, matrix comets and gerbs.

A relatively small group of stars sat on the 8 mesh screen, shown in Figure 10. These could be used in larger diameter matrix comets, gerbs, cake shells, micro mines and small bore rocket headings.

From the 1000g of mixed star comp, only 3 g were lost as unusable dust. Compare this with the 7g that was lost in process from sticking to the roller, scoops, buckets, screens etc. Compared with other methods of making microstars, the dust production with this method is very low.

Conclusion:
This method of producing micro stars is the easiest I

have yet seen, and allows you to convert all of a given batch of powder into a small range of star sizes rather than relying on byproducts from other processes. If you have trouble finding star cores for making regular stars, you may be able to use this process to start your normal sized stars after a bit of practice. This is an advanced rolling technique and you may not get ideal results the first time, but with practice it can be made to work well so don't give up.

One might be left wondering if this same method can be used to produce grained black powder for lift and break. While this would work, I believe the resulting powder would be weaker due to two factors: 1) there are no sharp edges on the grains as in corned powder, thus flame propagation will be slower due to lowered ignitability; 2) these grains are denser than those produced in a powder press for corning, so less surface area is exposed compared to an equal weight of corned powder. If your goal is to produce lift and break powder without using a press and corning machine, then screened rough powder made as described here is a better and faster way to go about it.

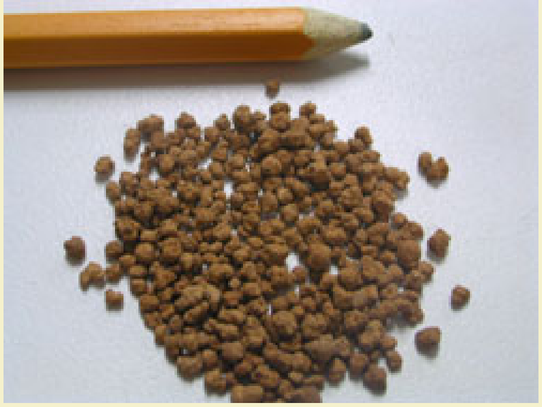
Figure 9: 55% passed through 8 mesh and sat on 15 mesh.

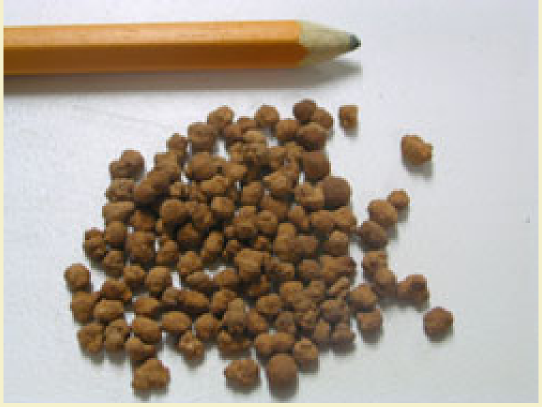
Figure 10: 14% were larger than 8 mesh.

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Design Notes...

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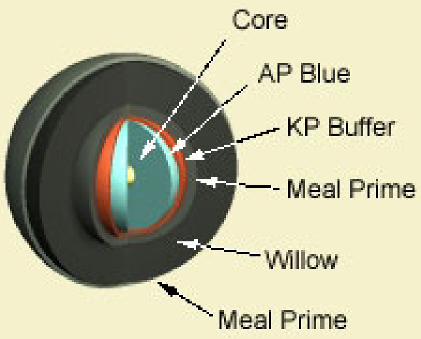
Round Stars, Part I

by Mitch Piatt and Kyle Kepley

Introduction:

The art of making round stars is perhaps one of the most difficult aspects of pyrotechnics to master. Poorly designed and manufactured stars will ruin a shell regardless of how well it is was assembled. Getting all your stars to ignite does not help when they burn too long, contrast poorly, fail to switch colors simultaneously or fail to all burn out at the same time. It is for this reason that shell competitions do not allow purchased stars except in the most entry level categories, as the quality of the stars play a large role in making a good shell.



This two part article will focus first on the planning and design of round stars, then on the star rolling techniques used for manufacturing them. This article will focus on the "what," while part 2 will describe the "how."

Before you can begin rolling, you must first design your star by answering the following questions:

1) What type of effect is desired?
2) What formulas are required for the effect?
3) Are the formulas compatible?
4) What types of prime are required?
5) What size should the stars be?

Design the Shell First

Star design begins with a good mental image of the shell you wish to make. You may want to imitate something you saw in a show, or you may have a unique design of your own. Either way, you must be able to visualize the entire sequence of effects and timing required by your shell. You are an artist at this point, not a scientist or technician. Do not think about the practical, only the color, sound and motion of animated fire.

A beginner shell builder will be more inclined to try various stars of different sizes and effects in order to get a feel for what they do. This is only natural, and quite a necessary part of the learning curve. Once the builder gets a feel for the visual effect and burn rate of different formulas, he may begin the real challenge of bringing a shell design from imagination to reality. Often the road to success is littered with trial and aggravating error, but such is the challenge that makes success in the end so rewarding.

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Round Stars, Part I...

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Know Your Formulas

Having a good library of familiar formulas to choose from is critical when designing stars. Most builders have a relatively small set of formulas they regularly use. These include deep and pastel versions of all the basic colors, various charcoal streamers and firefly effects, gold and silver glitters, gold and silver flitter, metal based special effect streamers and strobe formulas.

Building up your personal set of stock formulas will take time and lots of experimentation. It is best to test new formulas with small 300g quantities of pumped or cut stars before rolling stars with a new formula. Round stars are actually more difficult to make in small quantities compared to other types of stars. However, there are some types of formulas or effects that can only be done with round stars, so testing with other types of stars would not give the same results.

It is also necessary to test new formulas by shooting them from a star gun or shell rather than just lighting stars on the ground. A green that appears pale on the ground often looks much better 300 feet up in the air. The same holds true for purples and blues, while streamer formulas must also be moving through the air for the effect to be judged. Nothing is more frustrating than finishing a large batch of round stars only to burn them or shoot them out of a mine because they didn't perform the way you thought they would.

Once you have your working formulas picked out, you will start to become familiar with their burn rates, light output, color purity etc. You will figure out that AP stars have to be made slightly smaller than KP stars in order to burn for the same duration, or that silver flitter stars must be rolled larger because they burn very fast. You become familiar with the tradeoff between color saturation and light output for the various colors.

Last but not least, you become familiar with the way each composition rolls. Different compositions present different problems when rolling, and it becomes necessary to develop the techniques for dealing with these quirks. The most common rolling problems will be addressed in Part II of this article.

Chemical Compatibility

Chemical compatibility has long been a problem in fireworks manufacturing. Round stars typically have several different types of compositions layered on top of each other, and care must be taken to insure that hazardous chemical combinations do not occur. As a general rule of thumb, potassium perchlorate is compatible with all other standard oxidizers. This makes it good for intermediate buffer compositions between incompatible star mixes.

There are some chemical combinations so hazardous that the two chemicals should never be used within the same star, even when separated by buffer layers. This is especially true of chlorates in combination with ammonium compounds, which will form the extremely sensitive explosive ammonium chlorate.

Other chemical combinations will simply cause the star to fail, such as nitrates in combination with ammonium compounds, which form the extremely hygroscopic ammonium nitrate and leaves you with soggy stars that will not burn.

Some chemical combinations result in a more sensitive mixture, elevating the level of risk and care that must be taken. These combinations may not present any problems for a long time, giving the builder a false sense of security, then one day result in spontaneous combustion without warning. This is the case when using chlorates with any sulfates, sulfides, sulfur, lampblack or finely powdered metals.

The following table outlines the more common chemical combinations to avoid between two formulas that will be in contact with one another. Some combinations require a buffer between them if used in the same star, while those marked as dangerous should never be used in the same star even if separated with a buffer layer.

Contained in Formula 1	Contained in Formula 2	
	Requires a Buffer	**Dangerous**
Potassium Nitrate Strontium Nitrate Barium Nitrate	Ammonium Perchlorate	
Potassium Chlorate Barium Chlorate	Sulfur Sulfides Sulfates Hexamine Sodium Oxalate Lampblack Naphthalene Calcium Carbonate Chromium or Chromates (never wet with hard water)	Any ammonium compound Red Phosphorus
Ammonium Perchlorate	Potassium Nitrate Strontium Nitrate Barium Nitrate	Any chlorate compound

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Primes

There is no quicker way to ruin a perfectly good batch of round stars than incorrectly priming them. Once a prime is applied that is incapable of igniting the underlying star, there is no way to undo the damage. Some star formulas require no prime at all, while others require a series of two or three prime layers.

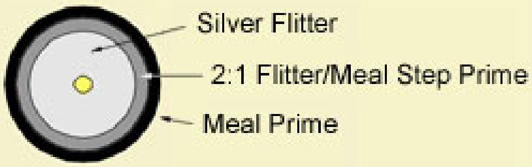
Beginners are often frustrated with the lack of prime specifications for the formulas they encounter. Even when prime specifications are given, it is still a good idea for the builder to verify that the prime is adequate before rolling it onto a batch of stars for the first time. A simple test can be done by flattening down a small amount of prime comp and placing an unprimed star on top of it. If the prime fails to ignite the star when it is burned, then chances are it will not light the star when it is rolled onto it either.

When basic meal powder fails to ignite a star, there are several alternatives that can be used as a "first fire" (the term given to the prime layer that is in contact with the actual star composition).

STEP PRIMES

A step prime is a type of prime made from ratios of the star composition mixed with meal powder. It is typically used with stars containing a lot of metal, which require high ignition temperatures. The meal helps lower the ignition temperature of the prime layer, while the star comp yields the high temperatures needed to ignite the star.

A typical first prime would consist of 2 parts star formula to 1 part meal. If this does not ignite the star, then the percentage of star comp is increased. If straight meal will not ignite this prime, then a second prime layer with a higher percentage of meal is used. The basic idea is to increase the concentration of meal in successive prime layers to the point that pure meal will ignite the last layer, making the final prime layer 100% meal.



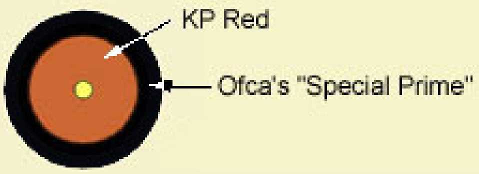
Formula: Silver Flitter

While step primes can result in 2 to 4 layers of prime, this method eliminates the need to mix up special prime formulas. You simply mix enough of the original star comp to account for the amount required for priming. Note that the star comp must be compatible with meal for this method to work. Meal must not be mixed with formulas containing chlorates or ammonium compounds.

OXYGEN DEFICIENT PRIMES

An oxygen deficient prime works well for stars that will be used in shells with flash bag breaks. Flash break shells are more common for plastic ball shells, but have a tendency to project the stars at a very high velocity to the point of blowing out the flame and creating "blind" stars. Oxygen deficient primes are black powder type primes with a high charcoal content. While this type of composition barely burns on the ground, it utilizes the increased oxygen from high wind speeds when exiting the shell to keep the star burning.

Bill Ofca has developed a flash/prime system that works similar to the oxygen deficient prime concept. With this system, he takes star ignition one step further by using a flash break that creates potassium and aluminum sulfide droplets which embed themselves into the prime layer of the stars. More on this system can be found in Ofca's Technique in Fire-Volume 3, "The Design and Assembly of the 6 Inch American Crown Chrysanthemum Shell."

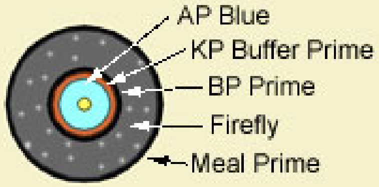


Formulas: Ofca Prime, KP Red

HOT MEAL PRIMES
In many cases an effective prime may be made by using meal with small amounts of metal powder or powdered silicon to increase the burning temperature. This type of prime often does not require a final meal prime layer, as the percentage of metal is not enough to effect the ignitability of the meal. A typical prime might consist of meal and medium flake aluminum in a 40:1 ratio.

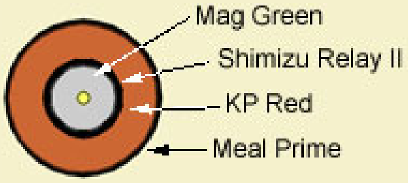
BUFFER PRIMES
Buffer primes are often used in color changing stars that contain incompatible chemicals. If a potassium nitrate glitter mix is being used over an ammonium perchlorate blue, then a buffer would be needed between the two layers. Without the buffer, the nitrate would leech into the AP core and ammonium nitrate would be formed, creating a hygroscopic star that would soon turn to mush.

In most situations, a potassium perchlorate based buffer prime applied with 4-6% NC lacquer will prevent any dissolved nitrate from breeching the buffer prime. This prime is also used between ammonium perchlorate stars and the final meal prime.



Formulas: KP Buffer Prime, AP Blue, Firefly

COLOR CHANGING RELAYS
While not serving the same purpose as a prime, color changing relays consist of a thin prime-like layer of low-light output composition sandwiched between the two color layers. The purpose of this relay is to enhance the effect when transitioning between colors, causing one color to fully extinguish for a split second before the second color flashes back on. Without the color changing relay, there can be a blending of colors during the transition from one color to the next, marring the effect.



Formulas: Shimizu Relay I, Shimizu Relay II, Mag Green, KP Red

FINAL PRIME LAYER
One of the most pleasing effects produced by round stars is a simultaneous shift from one effect or color to another. The more exact the timing of the transition is, the better the effect. While one key to achieving precise timing is to size the stars very accurately when making them, it is also important that the stars be primed with a final layer of fast burning meal. When a good round star is ignited, the flame should race around its entire surface almost instantly so that the star begins a uniform burning progression toward its core.

Stars with a slow outer prime will not be capable of clean effect transitions, as the first point on the star that takes fire will reach the core before the rest of the star, resulting in the inner color bleeding through before the previous color has finished. Even a layer of relay composition can not make up for an outer prime that is too slow. While a star that consists of something like Tiger Tail to green will take fire without a final meal prime, failure to finish the star with a fast prime layer will result in a tiger tail break that slowly fades to green.

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Size Matters

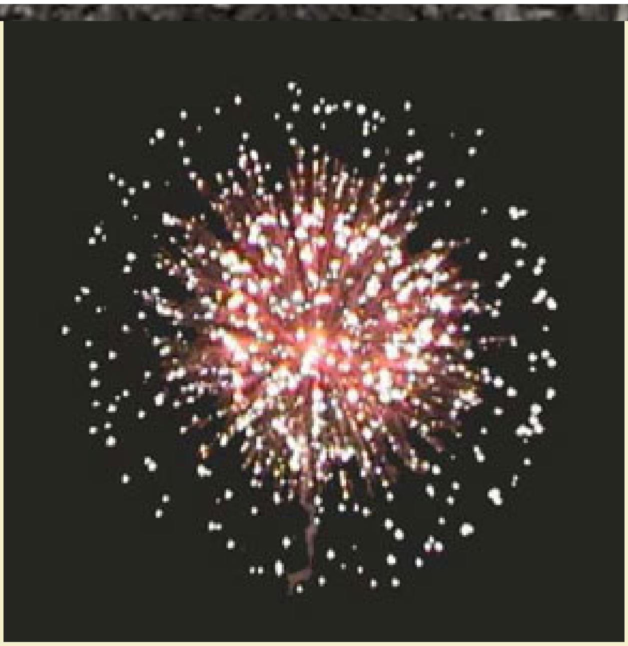
One of the finer aspects of designing round stars is determining the proper thickness of each layer required to achieve the desired effect. For solid color stars the process is pretty straight forward, but color changing stars timed to perform in coordination with other stars in two or more petals can be a challange.

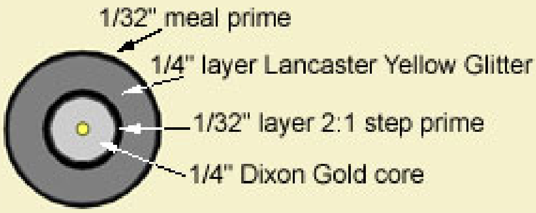
At the most basic level, the size of the stars in a shell will determine both the density and span of the break. Using 3/4" stars in a 6" round shell would produce a rather sparse break with a drooping umbrella effect as the stars continue to burn beyond the short amount of time a spherical break can fight against the effects of gravity. This may be the desired effect in the case of long tailed streamers or bright magnesium stars, but looks rather odd if ordinary color stars are allowed to linger for too long. If the same 6" shell were filled instead with 3/8" color stars, a dense break with a short lifespan would result. If the 3/8" stars were rolled from a slow burning comp and used to completely fill a flash bag type shell, an attractive waterfall effect would result.

The size of individual layers within the star plays an important role in the timing of one or more color changing petals. For example, say you wanted a 6" double petal chrysanthemum with a blue inner petal and an outer petal that transitioned from willow streamer to electric white at the end of its expanse. Due to the smaller space available to the inner petal sphere, the blue stars would need to be as small as possible while still having enough burn time to last close to the point where the outer petal transitions to white. If a slower burning AP blue was used, one could get away with using 1/4" stars, otherwise 3/8" would be a good starting point. The electric white at the core of the outer petal stars would not likely take fire from the willow, thus a prime layer would be required. The white cores would be rolled slightly smaller than 1/4" such that when the prime layer is added the final size would be right at 1/4". Since the star is not really switching from one color to another, rather from a streamer effect to a color, no relay layer is necessary. Depending on the burn rate of the willow comp, the remainder of the star would be rolled out to between 1/2" and 9/16". Since this is a color changing star, it is important that a final prime layer of fast meal is used to insure instantaneous ignition accross the entire surface of the star.

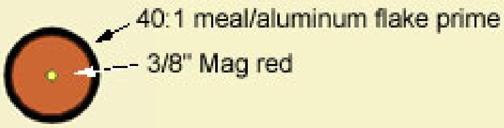
It often helps to draw a cross section of the star you intend to make, with each layer labled as to its thickness and effect. The following illustrations show a double petal break along with the star designs used to create it. Creating this template for a shell design employs all the aspects of star design covered thus far. Next month we will examine the procedure for manufacturing various stars using a star rolling machine.

9/16" Dia. Outer Petal Stars




1/32" meal prime
1/4" layer Lancaster Yellow Glitter
1/32" layer 2:1 step prime
1/4" Dixon Gold core

3/8" Dia. Inner Petal Stars



Formulas: Lancaster Yellow Glitter, Dixon gold, Mag Red

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Star Roller Reviews

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Technique...

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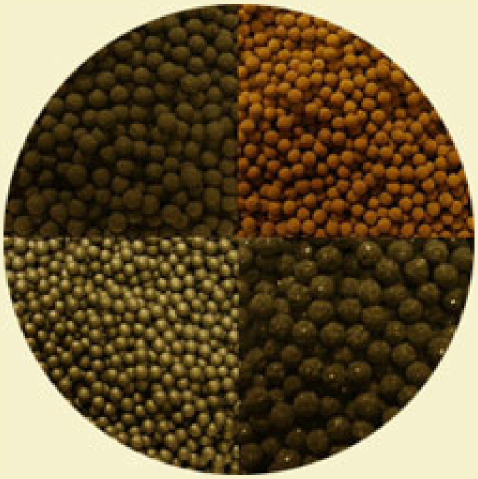
Round Stars, Part II

by Mitch Piatt and Kyle Kepley

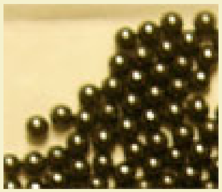
Introduction:
In Part I of this series we looked at round star design, taking into consideration such things as formula compatibility, primes, timing and sizing. This month we take a look at the actual manufacture of round stars, examining the following aspects:



1) Types of cores
2) Solvents
3) Rolling Techniques
4) Screening
5) Priming
6) Drying

Star Rolling Cores

All round stars are made by rolling successive layers of composition over increasingly growing spheres. Naturally, the process must begin with small cores upon which to build from. There are a wide variety of cores that may be used, with different advantages and disadvantages to each. The following table lists the pros and cons of common cores:

Core Type	Advantages	Disadvantages
 Lead shot (#8 or #6)	Lead shot rolls easier than any other core type. The heavy weight helps the cores pick up composition, and also helps maintain more size consistency during the early stages.	More costly than other core types. Sometimes the graphite may need to be removed so that composition will adhere to the surface, although some builders report no problems in this area. Fallout is thought to be another potential problem, although some believe that the shot vaporizes when the star burns up.
Millet (bird seed)	Probably the cheapest core type that can be used.	May require screening to remove grit if the pure variety can not be found. Due to the smooth husk of the millet seed, some report having to coat the millet with clay first before the composition will adhere. Like wheat paste, bugs also like to get into millet and slowly devour it over time.

Husked Millet (human grade)	More expensive than animal grade, but still very cheap. A 25 lb bag can be purchased from Whole Foods grocery stores for about $20. The size is smaller than normal millet, but the smooth surface has been removed, allowing composition to stick to the surface without any special preparation.	The small size may prove hard to work with for beginners learning to roll stars for the first time. If you don't have access to a Whole Foods store, it will also have to be mail ordered. Like wheat paste, bugs also like to get into millet and slowly devour it over time.
Molecular Sieves	Perfectly round, easy to roll, can be pre-soaked to make the initial coating process easier.	More costly than other core types, and can be hard to find when hobby suppliers are out of stock.
Pasta	Can usually be purchased locally.	Gets too sticky when first dampened unless pre-coated with something waterproof like NC lacquer. Known to swell when damp, causing finished stars to crack under some circumstances.
Tapioca	Good when large cores are needed for large stars, easy to roll.	Too large for most rolling. Can break apart when rolling.
Micro Stars	Easy to make.	Can result in irregular shaped stars depending on how the micro stars were made. Light weight can make rolling difficult for beginners learning how to roll.
Cut/Pumped Stars (1/4" size)	The slowest part of rolling, getting from core to about 1/4", is already complete.	Can result in irregular shaped stars unless rolling up to at least 1/2" size. May not produce accurately timed color changes.
No Cores	Ideal way to make micro stars under 3/16", since no core will leave more composition available to extend the burn time of the star.	Technique can be tricky to master. Sizing is very inconsistent.

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Round Stars, Part II...

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Solvents

Rolling round stars involves a continuous cycle of spraying the stars with a wetting solution and then adding the composition. The type of solution used depends on the type of composition you are rolling. In a perfect world, each formula you ever came across would tell you what type of solvent to use when rolling the star. In reality, this information is not always provided.

Water/Alcohol

In most cases, a simple mixture of alcohol and water may be used for spraying the stars. The alcohol is used to help lower the surface tension, which reduces the tendancy for stars to stick together when they are in the early stages of rolling. The alcohol also speeds up the drying process, which helps prevent a condition in which the star surface dries before the core does. This problem, called "driven in" moisture, can result in stars that effectively never dry.

Since most compositions bound with water and alcohol contain dextrin, it must be noted that dextrin is only solvent in water and not alcohol. Using a solution that contains over 50% of alcohol can weaken the integrity of the star by reducing the binding power of the dextrin.

It is common to begin the star rolling process using a solution with a higher alcohol content like 40% in order to reduce the tendancy of small cores to stick together. This percentage is then cut back to around 15-20% once the stars grow close to 1/4". The more alcohol that is in the solution, the slower the stars will grow. This is why it becomes advantageous to cut back the alcohol level to the minimum amount necessary to prevent rolling problems and still aid in the drying process.

Another star rolling problem that alcohol helps reduce is a phenomenon known as "spiking." Spiking occurs when stars develop bumps on their surface that grow larger as the star is rolled, deforming the desired round shape into a lumpy mass resembling a raspberry. The problem occurs most frequently in compositions that contain very finely powdered ingredients such as ball milled meal, lampblack, air milled red gum and charcoal. The theory is that these fine powders create a "skin" layer that shrinks when dampened, causing tiny hills and valleys on the surface. The hills naturally collect more powder, while the valleys get none. Alcohol lowers the surface tension of the water, which in turn helps avoid the shrinkage problem.

Color resin stars that contain red gum need little or no alcohol in most cases. Up to 15-20% can be used to help break the surface tension, but too much alcohol will cause the resin to become too sticky to work with. This sticky layer has also been known to form a moisture barrier and cause the driven in condition.

In star formulas that contain nitrates in combination with fine aluminum powders, there is a tendancy for the nitrate-aluminum reaction to generate heat which further accelerates the reaction. The presence of alcohol in the solution helps to cool the mixture through evaporation, thus helping prevent a nitrate-aluminum reaction from heating up.

Dissolving 1% boric acid into your spray bottle will also help prevent the nitrate-aluminum reactions from occuring. Note that dissolving the boric acid into your solvent is more effective at preventing the reaction than screening the boric acid into the star composition itself. The boric acid dissolves slowly, however, so prepare the solution a few hours before it is needed.

Alcohol/Acetone

Some star formulas contain metals such as magnesium that simply can not be bound with water due to spontaneous combustion risks. These types of stars use parlon as both a chlorine donor and a binder when dissolved in acetone. The parlon not only binds the star, it also coats the magnesium and protects it from moisture.

Alcohol is added to the acetone in order to slow down the rate of evaporation. Stars bound with acetone must not be dried in a tub or other container with a closed bottom and sides. Acetone fumes are heavier than air and will remain in the tub, preventing the stars from drying. Acetone fumes are also hazardous to your health as well as highly flammable, so rolling such solvents outside with a vapor mask is highly recommended.

NC Lacquer/Acetone

This type of binding solvent has a unique advantage in that it creates a moisture resistant star. It is typically used to apply buffer prime layers between incompatible layers such as ammonium perchlorate (AP) and nitrate compounds. If a nitrate formula were rolled directly onto an AP core, the water would carry dissolved nitrates into the AP core and create ammonium nitrate, effectively ruining the star. Using NC lacquer diluted to a sprayable consistency with acetone eliminates this problem.

This solvent can also be used to roll a prime layer onto a star which is hygroscopic, thus preventing the star from absorbing moisture in the air and ruining it.

Note that if NC is used to bind charcoal streamer stars, then the tailed effect will be greatly diminished, ruining the star. If used to apply the final prime layer, there is also a tendancy to create a fire-block which will prevent the star from igniting. In this case, a final meal prime must be applied over the NC layer using just water as the binder.

This solvent is a particularly troublesome one to deal with, as it destroys any rubber components of your sprayer, dries overly fast, has very strong fumes that require a vapor mask and heavy ventilation, causes stars to roll very slowly and leaves a mess in your star roller that must be washed out using acetone. In spite of all this, there are effects where its use can not be avoided.

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Round Stars, Part II...

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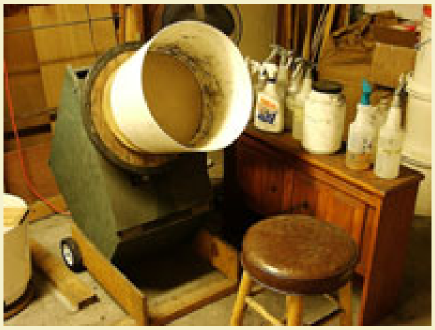
Figure 1: A home made star roller.

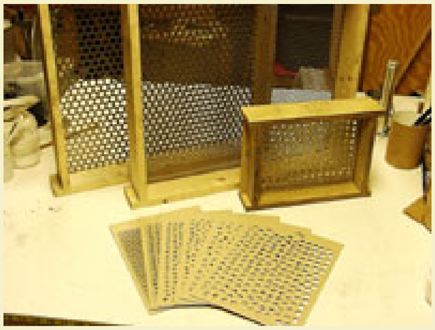
Figure 2: Sizing screens.

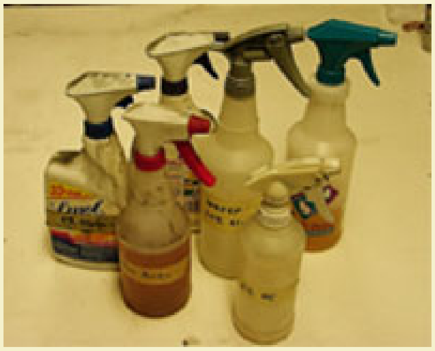
Figure 3: Various spray bottles.

Getting Ready to Roll:
This article deals specifically with rolling stars using a star rolling machine. While it is possible to manually roll stars in a large bowl by swirling them around for long periods of time, this method is tedious and impractical for making large quantities of stars. If you are interested in this manual method, David Bleser has produced a video that details the process, available from AFN.

The first thing you will need is a star rolling machine. This month's Tool Tip reviews several star rolling machines that can be purchased or fabricated.

Next you will need a set of screens so that you can produce accurately sized stars. The best star sorting screens use round holes instead of a wire mesh. Perforated sheet metal is available that contains a dense array of round holes, which can be framed into a box frame. You can also make your own screen by drilling as many holes as possible into plastic or aluminum pans. Common screen sizes are 3/16", 1/4", 3/8" and 1/2". I prefer to have additional screens that are 1/32" above these sizes for cases in which very accurate sizing is required. Figure 2 shows both the perforated metal screens and a small screen with interchangeable plastic sheets that were hand drilled for the various sizes.

You will also need a method of spraying a fine mist of solvent onto your stars as you roll them. Hand pumped spray bottles are the most common method when starting cores and making small to mid size batches. Hostile solvents such as NC lacquer and acetone require special spray bottles that will hold up to their tendancy to dissolve rubber grommets, o-rings and pump valves. Lysol and 409 household cleaner bottles seem to hold up well to these solvents.

When rolling larger batches of big stars, the amount of solvent that must be sprayed between powder applications becomes tedious to apply with a hand pump spray bottle. In this case a pump-up weed killer sprayer or compressed air paint spray gun works well. The compressor for the paint gun method must be turned way down to around 10psi in order to prevent the air output from from blowing the powder around in the roller and making a mess. Most weed sprayers do not produce a fine enough mist for working with small stars, making it easy to over wet them.

Before you begin you will need to measure out a volume of cores to start with. These may be your starting cores or stars that have already been rolled up to a certain size. A small amount of starting cores will produce a lot of stars, even if you are only making 3/8" stars. Generally 1/4 cup of cores is a good starting point. If you are using larger cores like tapioca or lead shot, then you can start with slightly more. Small cores like husked millet may require slightly less. If you are expanding stars that have already been rolled up to a certain size, then you will want to start with quite a bit more. For example, if you are starting with 1/4" stars, then you might start with something like two cups of them. Only after experience using your own star roller will you get a feel for how many cores to start with.

If you are using hostile solvents such as acetone or NC lacquer, it is a good idea to strap on some latex gloves to avoid skin contact with these solvents. Use of latex gloves also keep your hands clean and make cleanup easier.

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Rolling Techniques

The techniques for rolling round stars include subtleties that make it one of the more difficult aspects of pyrotechnics to master. Each type of star comp has different rolling characteristics, and even different rolling machines take some getting used to. The techniques of star rolling are difficult to convey through text, and the reader must ultimately spend a good bit of time actually rolling stars before mastering the process.

Begin by pouring your cores into your roller and starting it up. Give them a small burst of spray from your spray bottle, which may cause some of them to stick to the sides and begin rotating all the way around with the drum. This will usually occur with small, light cores like husked millet or pasta cores. Lead shot or molecular sieves should not cause this problem. Whenever you over wet the stars and they stick to the walls or each other, use your hands to scrape them off the sides and roll the damp cores around between the palms of your hands to separate them and distribute the moisture.

Your first powder increments at this early stage should be very small. Just enough so that the stars pick up all the powder and appear dry on the surface. Continue to alternate between small bursts of spray and small increments of powder.

It helps to avoid spraying the walls of the roller at this early stage, as comp will adhere to the wet walls instead of the stars. This will then result in clumps of composition on the roller walls that continue to grow as the stars grow, robbing composition from them. When the stars are larger than 1/4", a technique can be used to transfer the comp stuck to the bucket walls back onto the stars by spraying the patches of comp directly and let the stars roll over them. The stars will eventually pick up the overly wet comp off the walls, cleaning up the mess.

When the stars are still small during the early stages, spraying the sides of the bucket will cause them to easily stick to the walls and over wet them. A second method of cleaning the bucket walls involves just scraping the mess off with your hands and throwing it into the rotating star pile. The star pile is then rolled between the palms of your hands in order to grind up the larger chunks, which will fragment into tiny pieces that become new star cores. If your stars fall apart while doing this, then you are rolling them too dry. Add more solvent between powder increments.

When you look closely at the rolling mass of stars, you will notice that the larger stars are seen on top and to the front of the pile. The smallest ones are at the bottom and can be seen at the back corner and along the rising edge. This is an unfortunate characteristic, since it means the largest stars are in the best position for acquiring water and powder, while the stars that truly need to catch up in size are stuck at the bottom of the heap. The social injustice of star rolling causes the rich to get richer!

In order to keep the stars from developing into drastically different sizes, there are a few techniques that can be used. One method is to sweep your hand under the pile of stars and turn them over right before spraying them, then quickly adding the next powder increment. This brings the small stars to the top, but they won't stay there for long.

Another method of keeping stars at the same size works for certain types of compositions and can only be used once the stars are about 1/4" or larger. The method involves spraying the sides of the roller where the stars will be rolling, such that the stars on the bottom of the pile will roll over the damp areas and pick up the water. The powder is then applied to the rising edge of the pile, where the smaller wet stars can be seen coming out from under the pile. This method is quite effective at maintaining equal star sizing, especially with larger stars, but will not work with compositions containing fine aluminum powders that easily stick to the roller walls.

When the stars are still below 3/16" diameter, there will be a lot more junk that won't roll up, such as large aluminum flake or parlon flakes, in addition to scraps of comp that are continuously forming new stars. This is due to the light weight of the stars combined with the small radius that particles have a hard time sticking to. These problems are less when rolling with lead shot, since the extra weight helps the stars compact more composition onto themselves.

Once the stars reach 3/16", it is a good idea to empty them out of the roller and screen out all the smaller stuff. The small scraps can be used as cores later if you do not get the quantity of stars that you desired. The 3/16" and everything above that size is returned to the roller for continued rolling.

As you approach the destination size of your stars, you can use a circle template or a drill bit guide to check their diameter to see when you are getting close. Once you are almost there, it helps to stop spraying the stars any further and add an oversized powder increment. Let the stars roll with the pile of powder riding on top of them until they pick it all up. This excess powder will wick some of the moisture out of the star and reduce the drying time. If they pick it all up and still seem heavy and overly damp, add another increment and walk away for a while. The surface of the stars should not be shinney or wet to the touch. They also should not stick to each other when the star roller is turned off.

Once the stars reach 1/4" in size, it is a good time to stop there and dry them before continuing further. The stars are poured out onto newspaper or preferably a screen that is held in a drying rack.

You will often want to put aside a quantity of 1/4" stars for use in color changing stars, then continue rolling a portion of them up to larger sized color solid stars. Some builders recommend that the thickness of new composition you roll onto a dry core not exceed the radius of the core. This is to help keep the star from getting too wet at the center and risk becoming driven in. Thus, the maximum stopping points would be 1/4", 3/8", 9/16", 13/16" etc. However, in most cases you want a range of stars that increase by 1/8", so you would add 1/8" thickness per rolling session. Stars may also be rolled from a core to 3/8" with no problems, or from 1/2" to 3/4". It really depends on the type of composition you are rolling and how wet you roll your stars.

There is another method of star rolling that involves adding oversized powder increments as mentioned previously, then spraying the stars repeatedly until they pick it all up. My experience with this method is that, while it is faster, it is harder to maintain good size control. However, it is a method that is used in industry to produce large quantities of stars, and can be very productive when used with a dozen or more star rollers running in parallel. In this case, a single operator can move along the line, adding powder to one roller after the other without having to waste any time waiting for composition to pick up. By the time he gets to the last roller, the first one has finished picking up the composition and is ready for more.

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Round Stars, Part II...

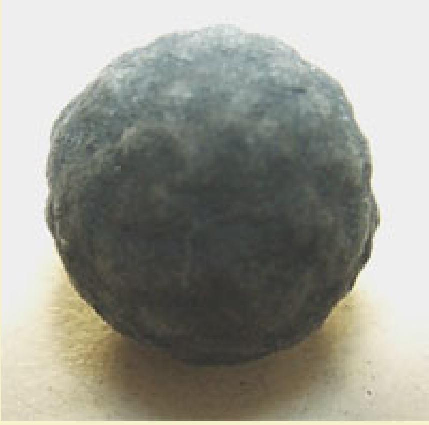

Figure 4: Closeup of slightly spiked prime surface.

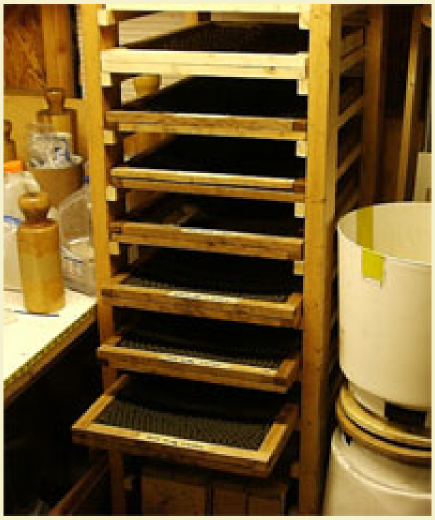

Figure 5: Air drying rack.

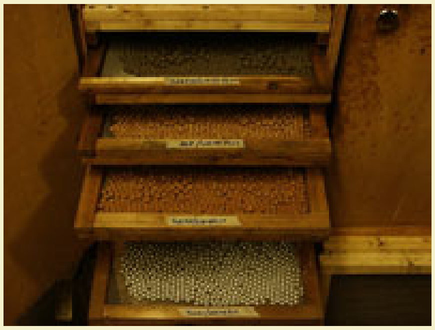

Figure 6: Forced drying box.

Screening:

It is important that all the stars produced from a given batch of round stars be as close to the same size as possible. Not only does this help the stars stack nicely when loading them into the shell, it is critical for simultaneous color changes and burn outs.

It is often difficult to keep all the stars the same size through rolling technique alone, thus they must be periodically screened during manufacture. Samples must periodically be taken while rolling, choosing the biggest stars and using a circle template to see if they have reached the destination size. Whenever a noticeable amount of stars have reached the final size, they must be screened out to keep them from growing too large. You may need to screen your stars two or three times during a rolling session if larger stars insist on developing ahead of the other stars.

Priming:

All stars should be fully dried before adding the final meal prime layer. This is because good meal powder is very fine and dries into a dense crust, which can easily cause a star to become driven in if there is moisture locked in below the prime layer.

Stars may not always become driven in by adding the prime right away after rolling the stars, but waiting until they are dry will speed up the drying time. The prime layer usually only requires about one day to dry when applied to a dry star, whereas adding the prime to a wet star can increase the overall drying time by a week or more. The degree that this phenomenon occurs is proportional to how finely powdered the meal powder is.

Meal prime is best applied with 100% water, and the powder increments should be a little oversized so that the stars are overly dry. This is to intentionally cause spiking on the surface, which creates a rough texture that aids in ignition and helps prevent the star from being blown out at high speeds. The spiking should be noticeable but not excessive, as seen in Figure 4.

Drying:

While stars may be dried by placing them on trays lined with newspaper, a more effective method is to place them on a screen so that the stars are exposed to more air. Wooden frames fitted with window screen are commonly used for this purpose, or even window screens which already have the frame on them. The stars are best arranged into a single layer, as opposed to piling them into two or more layers. This insures that all stars dry at the same rate.

When drying stars on screens, the drying is most effective if the screens are suspended in mid air rather than sitting on a table. The drying rack pictured in Figure 5 allows many screens to be suspended while consuming a minimum of valuable shop space.

After stars have air dried for several days, they may be moved to a drying chamber to speed up the final drying. Such "dry boxes" usually consist of an enclosed screen rack with an internal dehumidifier, a slight heat source and a slight air flow. Figure 6 shows one such dry box being used to "force dry" stars, the term given to the process of speeding up the drying process using controlled conditions.

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Round Stars, Part II...

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Trying to force dry round stars usually results in problems unless they are allowed to air dry in the shade for at least a few days. They may then be dried in the sun or placed in a drying chamber. If a star is placed in the sun or drying chamber directly after being rolled, the first 1/16" of the star will be dry within a few hours, then the rest of the star will take weeks or even months to fully dry. Trying to save time in this way often backfires and increases the dry time substantially.

Stars may occassionally develop cracks in the surface during drying, which can be caused by force drying compositions which slightly shrink upon drying. If the surface completely dries while the underlying comp is still fairly damp, cracks may develop. This flaw can often be repaired by putting the stars back in the roller and rolling them while re-wetting the surface with water. This same technique can sometimes be used to salvage driven in stars as well, except in the case where NC lacquer was used to roll the stars.

Stars containing barium or potassium chlorate should not be dried in the sun at all. Ultraviolet rays from the sun can liberate chlorine dioxide which will break down the chlorate into chloric acid, creating the risk of spontaneous combustion.

Stars containing nitrates in combination with aluminum or magnalium should also not be dried in the sun in order to prevent the acceleration of any aluminum/nitrate reactions.

Storage:
The most common method of storing round stars prior to shell assembly is through the use of plastic ziplock bags. These are cheap and easily labeled, and this type of non-rigid container has the flexibility to allow many stars to be piled into a small box or magazine. The only drawback is the potential for static buildup in dry climates. Always place your hand inside the bags to feel for any static charges before loading.

While not as common among hobbyists, a safer and sturdier container for star storage should be made of paper or cardboard, such as spiral wound tubes with caps or brown shipping boxes.

Related Articles:
Round Stars, Part I
Star Roller Reviews

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Selections from "The Best of AFN II"

The Kamuro Star, pg 72
Making Round Stars, JBC, pg 74
Round Flitter Stars, DB, pg 78
Round Lampblack Stars, SC, pg 82
Sizing up Your Round Stars, DB, pg 88
Those Ugly Bumps on Round Stars, DB, pg 90
Pasta Cores for Round Stars, DB, pg 91
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Technique... **Page 1**

Rolling Precision Round Stars

Introduction:
Rolling round stars is probably the last star making technique most beginning pyros learn to master. The need for the rolling machine combined with the difficulty in rolling small batches of stars and the little nuances necessary to roll stars quickly and effectively create a barrier to entry for the beginner. However, round stars are the most versatile and precise type of star that can be made, and they are the only option for making color changing effects and round shells.

Some pyros will recommend that you learn to roll stars by hand in a metal bowl before using a machine. I disagree with this viewpoint, as the technique for rolling stars in a machine is much different than using a bowl. Swishing stars around in a bowl is labor intensive, difficult and limited to small batches. The beginner who approaches star rolling through this route is likely to lose all interest!

This article is intended for those already familiar with basic star rolling techniques as explained here. In this installment we look at one specific process for efficiently making a range of star sizes of the same color, also referred to as "rolling cores." We also look at how to size these cores to very precise dimensions in order to achieve commercial quality effect changes that occur in precise sequences.

When working with larger batches of stars, star rolling becomes the fastest method of making stars available. This is because it takes just as long to roll a one pound batch as it does a ten pound batch. Not only that, but rolling becomes much easier with larger batches. This is because the extra weight of the star pile helps the stars pick up composition easier, keeps the sides of the roller clean, reduces spiking and is just an easier task all around.

The down side to working with large batches of course is that when you mess things up you can waste a lot of material! The technique shown here is only recommended for compositions with which you are very familiar and have rolled successfully in smaller batches.

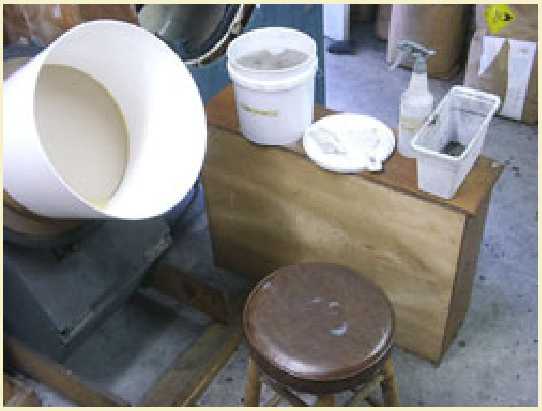

Figure 1: A typical star rolling station.

Rolling Star Cores:
Since it is easier to roll larger batches of stars, it makes sense to roll a year or two's worth of color cores in all the basic colors that you commonly use. These typically include red, green, blue, yellow, white, white flitter and strobes. I use the term "core" to refer to round stars between 1/4" and 1/2" that are a solid color with nothing rolled over them. Making a few pounds of cores in the 1/4", 3/8" and 1/2" sizes of the common effects mentioned above will give you a nice palette to choose from when building out the stars to completion.

Rather then starting from scratch each time you want to make a new batch of stars, having a good supply of cores on hand will allow you to skip the most time consuming step, which is bringing the star up from a small seed to the inner core size. You simply throw a few handfuls of your pre-made cores into the roller and start adding effects from there. A one gallon bag of 1/4" cores will make an amazing number of 1/2" stars, and will likely last you several years!

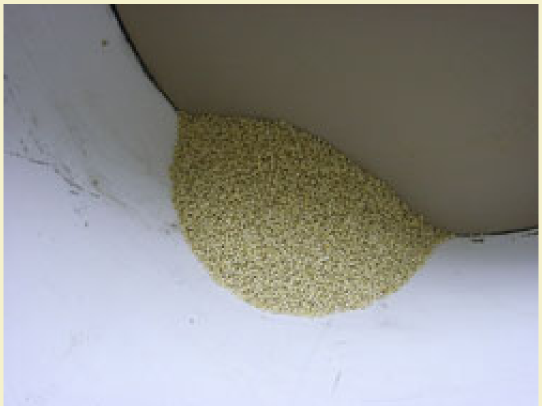

Figure 2: 2/3 cups of husked millet cores ready for rolling.

My starting core of choice is a seed known as husked millet, which is smaller than normal millet because the shiny outer shell has been removed. The smaller core you start with, the better micro stars you will be able to produce for use in gerbs and small shells. Using a large core such as lead shot or micro sieves will consume a high percentage of volume in stars smaller than 3/16", which will reduce their burn time. Husked millet is not as small as sand grains, but it is smaller than most other types of cores yet still cheap and easy to work with. I purchased a 25 lb bag of husked millet from Whole Foods for only $20, which will probably last a lifetime if the bugs don't get it. Transferring the seed from the paper bag into a sealed container is important to prevent the bug problem. If you do get a bug infestation, flooding the millet with water and drying it out will kill the bugs. Just make sure it is good and dry before sealing it up again!

Figure 1 shows a star rolling station ready for action. I use a 15" diameter roller that spins at 28 RPM for stars ranging between cores up to 1/2" in diameter. The drum sits about 3 feet off the ground, which is a comfortable level when sitting on a small stool for hours on end. A table next to the roller allows easy access to the powder bucket, sprayer, a scraper and a waste bin. It is a good practice to do your rolling out doors, especially when rolling dusty comps like aluminum and charcoal.

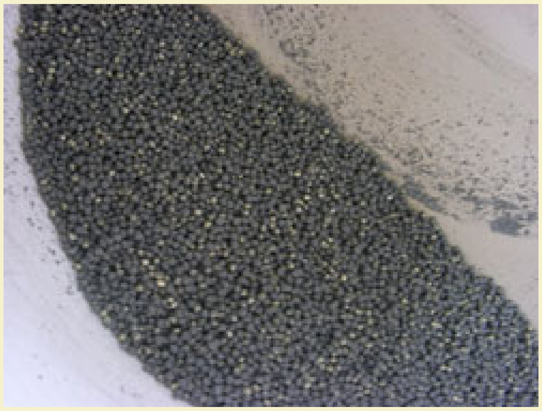

Figure 3: Initial buildup on the cores rapidly expands pile size.

Figure 2 shows 2/3 cup of husked millet ready to be rolled. You will need about 15 pounds of composition to work this millet up to the various sizes. This seemingly small pile of cores will make quite a large number of stars, even if you only roll them up to 1/4". Figure 3 shows how much the pile grows before even all the cores are fully coated.

The key to starting composition on small cores like this is to put on a pair of latex gloves and work the cores with your hands in between spraying and powder application. This helps break up the inevitable clumping that will occur, and also allows you to mop up caked powder that will adhere to areas of the drum dampened by your sprayer. Roll the stars between your hands or drag them across the bottom of the roller to help break up any clumps. For dextrin bound stars, using a higher percentage of alcohol at this stage will help reduce clumping. The exact amount of alcohol varies greatly depending on the rolling characteristics of the composition. Formulas containing a high percentage of parlon and magnalium can be started with almost 100% water, while formulas high in aluminum or charcoal content might need up to 50% alcohol to get them started and reduce spiking problems.

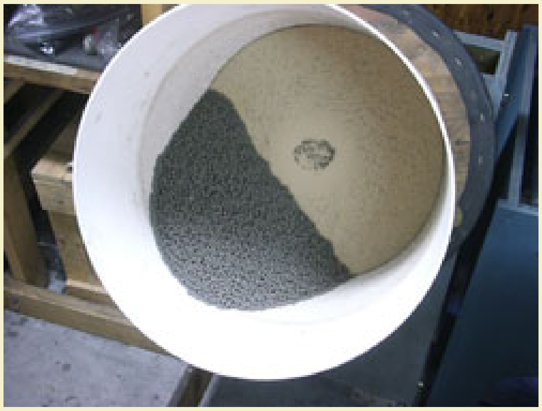

Figure 4: Rolling is stopped at about 3/16" diameter.

Figure 4 shows the original pile of millet rolled up to 3/16" diameter. Size consistency between stars will be very poor at this early stage, and there's nothing you can do about it. New stars are continuously forming from clumps of wet comp that break off, so there is generally a wide range of star sizes at this point. But that's ok, because these tiny round stars make great micro stars for your gerbs!

At this point the stars are placed on a screen lined with a sheet of newspaper and allowed to dry, as seen in Figure 5. Because star

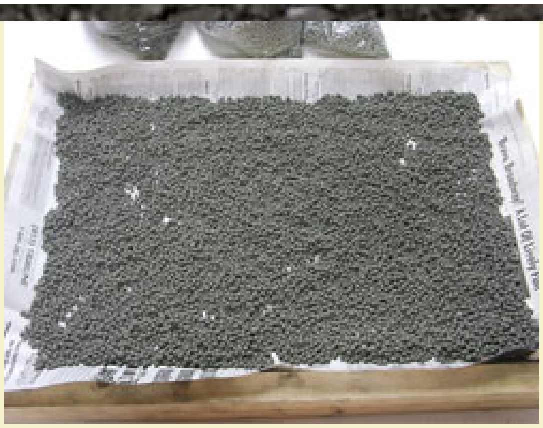

Figure 5: Stars placed on a screen lined with newspaper for drying.

rolling is an inherently boring activity and dust masks make you hot and sweaty, I only spend a small amount of time rolling at each stage. The true addict with a lot of screens and a high tolerance for monotony would clean the roller and begin to bring up the next set of cores, continuing the process until all the base effects were rolled up to 3/16".

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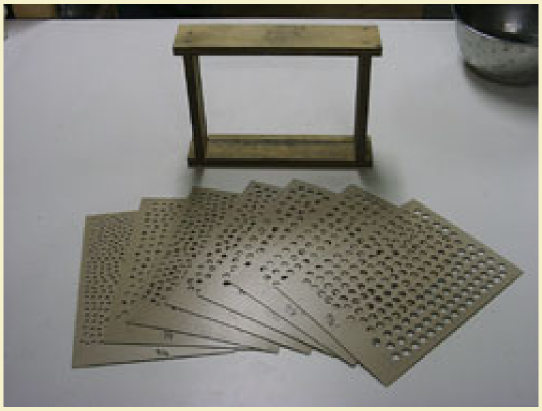

Figure 7: Screen box with interchangable screens.

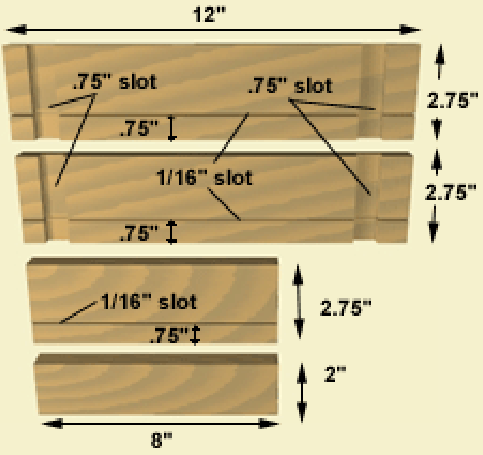

Figure 8: Screen box frame dimensions.

Screening Round Stars:
The key to any good round shell is good round stars, and good round stars can only result from good sizing technique. Poor size consistency will result in sloppy effect transitions. Anyone wishing to make a color changing ball shell that blinks from one color to the next with unified precision needs to start with a good set of sizing screens to achieve this.

Some people think I'm obsessive, but I actually screen my stars up to 3/8" dia. with 1/32" accuracy. While this may seem like a high tolerance, 1/32" of a 1/4" star is actually only a 12% tolerance. Screening to 1/16" simply results in too much size variance for precision color changing timing, but will work fine for simple solid color stars.

With a 1/32" tolerance, you find yourself needing more screen sizes of course. The screens listed in the process diagram on the next page call for 3/16", 1/4", 9/32", 3/8" and 13/32" screens. Since ordering such wide variety of odd sized perforated metal to use for screening would get expensive, I prefer to make my own. Because you are not going to be processing 100s of pounds of stars each day, a small 12" screen box will work just fine. Smaller screens are easier to handle and will be easier to build screens for.

Figure 7 shows a screen box with interchangeable screens that are made from sheets of Formica with holes drilled in them. The Formica drills easily without gumming up the bit and the thin sheets allow stars to drop through easily without getting stuck in the holes. Drilling the holes is of course a rather tedious task, but a drill press will help to make it easier. You only have to make the screens once and they will last a long time, so just think of it as a meditative exercise!

Figure 8 shows the dimensions for the screen box, which will require a table saw or radial arm saw to make due to the slotted groove and dado joints. Note the non slotted piece that leaves an opening for the sheets to slide into at one end.

Of course you can simply find some cheap plastic bins and drill a bunch of holes in the bottom as well. Some hobbyists drill holes in the bottoms of 5 gallon buckets and stack them up in order of largest to smallest, then dump their stars in the top and shake this "screen tower" such that the stars settle out at the various levels.

Figure 9 shows a screening operation in progress. You really need three bins: one to hold the initial star batch, one to catch the stars that fall through the screen and one to store the stars that stay on the

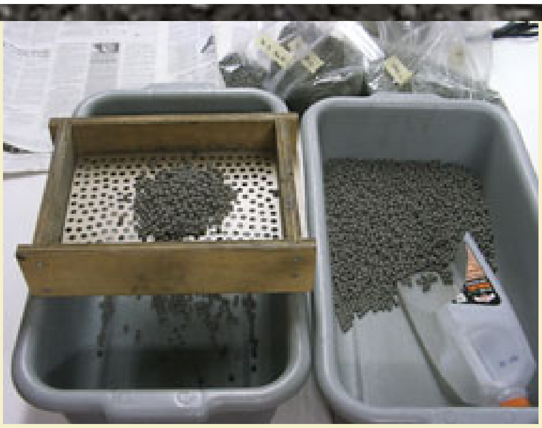

Figure 9: Screening setup.

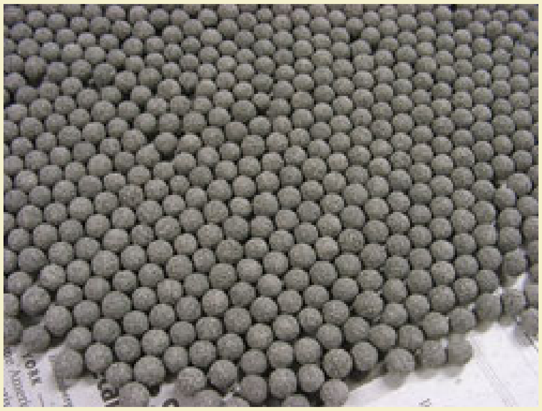

Figure 10: Well sized stars will align into a tight fitting pattern.

screen. A scoop made by cutting the bottom off a 1/2 gallon juice or milk jug makes an excellent star scoop. However, scoops such as this will sheer pieces of damp stars off, so only use it on dry stars.

The basic process is to roll a whole lot of 3/16" cores, screen out the sub 3/16" for use as micro stars and then roll the rest on to 1/4" stars. I prefer to dry the stars at 1/8" increments, which allows them to dry in only one day. Trying to roll too much comp onto stars in one sitting not only makes them take longer to dry, it requires you to screen them more frequently while still wet, which can be a source of chipping and other damage.

Figure 10 shows how a good batch of accurately sized stars will align themselves into a very snug and symmetrical pattern when laid flat. You should see hexagon outlines as each star aligns perfectly with those around it. You then know you have achieved the Zen of star rolling!

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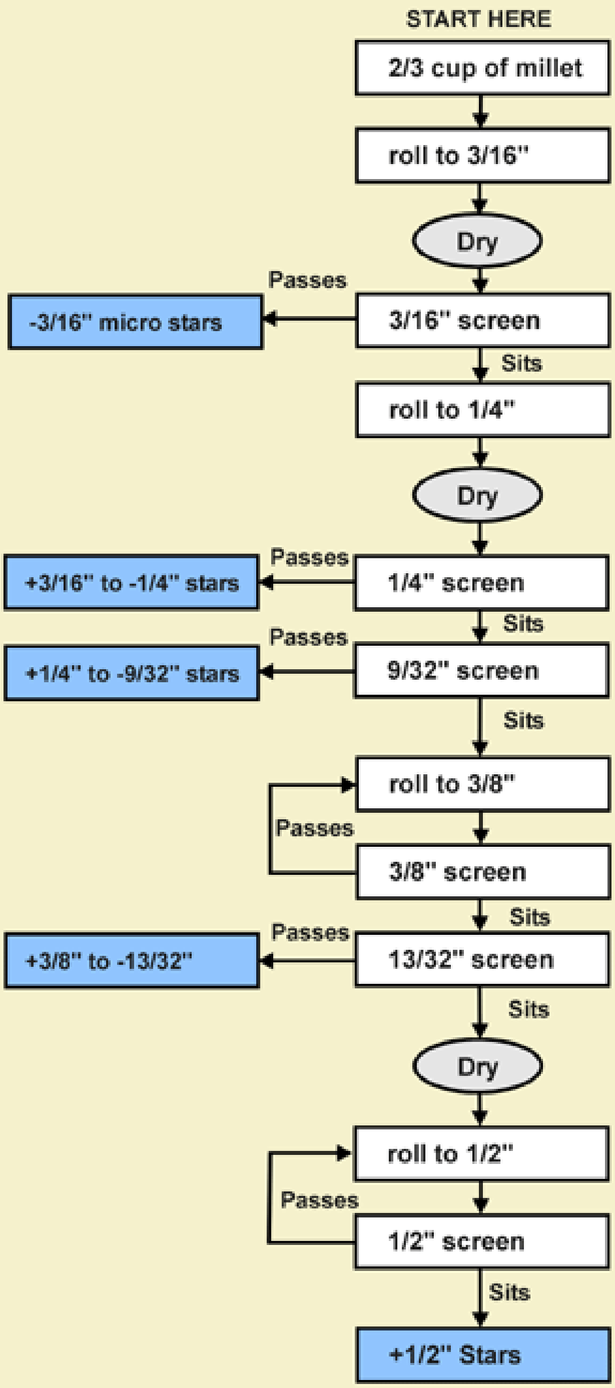

When rolling your stars and they start to look big enough, throw a handful on the next size screen you are rolling up to and see how many are retained. When about 50% sit on the screen, it's time to stop and screen again. Of course the more frequently you screen the better your batch size will be, meaning that you will get more of the size you are screening for and less of the oversized stars that must be rolled up to the next size. If you will be making another set of stars up one size from the current batch, you will need the oversized stars anyway so you might as well just screen less frequently.

The process diagram to the right shows the drying points, screen sizes and sort-to sizes that are your final products along the way. You will want to turn each 15 lb bucket of comp into the following bags of stars:

-3/16" a mixture of various sized micro stars for use in gerbs and small shells. These may also be rolled up later instead of starting from seeds again.

+3/16" to -1/4" these are fall-through from the first 1/4" screening and make good stars for small insert shells and matrix comets.

+1/4" to -9/32" these are your bread and butter cores for color changing stars. You will want a lot of these.

+3/8" to -13/32" these are good for smaller peony shells, pistil stars for double petal shells or cores for larger stars.

+1/2" to 9/16" these are used for mid sized ring pattern or peony shells.

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Design Notes...

Page 1

Strip Pasting Calculations for Paper Ball Shells

Introduction:

Whenever you fire a really nice paper ball shell in the presence of other pyros, you will likely receive two questions: "what did you break that with?" and "how many paste layers?" While the break charge will depend on the volume of space available and the type of effect desired, the thickness of the shell casing for a given caliber of shell tends to be a constant. There are special cases where a shell is required to have a weak break, such as parachute shells and go-getter shells that need to pop out their contents without throwing them across the sky, but the typical star shell requires a certain amount of confinement to achieve a good effect.

With large shells over 8" diameter, the thickness of the paste layer can mean the difference between getting out of the gun intact or rupturing into a flowerpot. With smaller shells, an overly thin paste layer will reduce the size and symmetry of the spread. Burst charges such as KP, which require a buildup of pressure in order to reach their maximum strength, can result in pathetic puffs of stars in an under-pasted shell.

While the most reliable method of determining the correct thickness of the paste layer is through experimentation, it would be nice to have a general starting point to work from. Shimizu has provided a formula for just such a purpose in his book "Fireworks, the Art, Science and Technique." This "traditional" formula is stated as follows:

N = 5.6 D(cm)/J(kg/cm)

Where N is the required number of layers, D is the outside diameter of the hemisphere to be pasted and J is the mean value of the tensile strength of the paper to be used. The J value must be measured for the type of paper you will be using, which is done by measuring the tensile strength of the paper in directions both parallel and perpendicular to the grain of the paper. These two values are added together and divided by two to get the final J value.

The constant of 5.6 was most likely arrived at by working backwards from a known number of pasted layers taken from a sample of working shells and equating this to the diameter and paper strength used for these shells. If you wish to work in English units of pounds and inches instead of the metric system, this constant is adjusted for the new units and becomes:

N = 79.5 D(in)/J (lb/in)

The remainder of this article illustrates how to measure the J value for your paper and use this formula. Measured values for different types of paper are presented, and a chart is tabulated that gives the number of layers required for common shell sizes.

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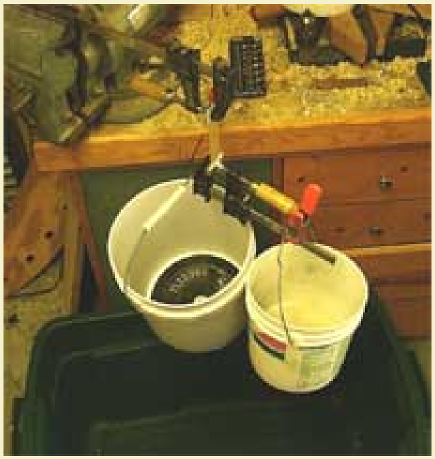

Figure 1: Bar clamps used in tensile strength measurement device.

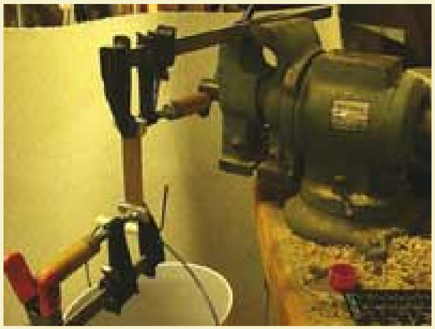

Figure 2: Another view of the bar clamps, held in place with a bench vise.

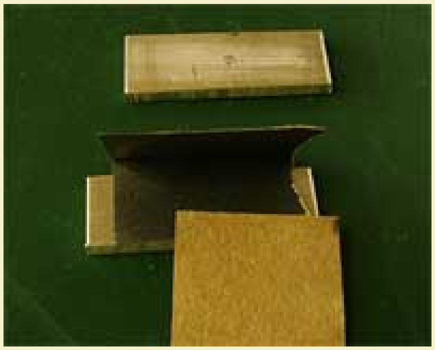

Figure 3: Aluminum plates and emery cloth used to evenly clamp the ends of paper strips.

Measuring Tensile Strength of Paper:
The setup for measuring the tensile strength of paper shown to the left operates by hanging weight from strips of paper and gradually increasing the weight until the strip pulls in half. The weight is then measured and recorded.

Paper strips of a fixed width must be prepared in sets of two for each type of paper being tested. The grain should be parallel to the strip length for one sample (grain long), and perpendicular to the length for the other sample (grain short). Any width of paper may be used, but making them either one inch wide or one centimeter wide helps simplify your calculations. Otherwise you will have to divide your breaking point weight by the width of the strip to get the desired number. Using strips wider than one inch will require an inconvenient amount of weight to break, while going under one centimeter may not even support the minimum clamp and bucket assembly weight. I used one inch wide strips for my tests.

Bar clamps are used to grip each end of the paper strips as tightly as possible. A small piece of emery cloth is first folded around the ends of the strips in order to prevent the paper from slipping from the jaws of the clamp. Each end is then sandwiched between flat pieces of aluminum as shown in Figure 3. This ensures that the entire width of the paper will be clamped, allowing tension to be distributed evenly across the paper. Failing to clamp the paper evenly across its width will result in an uneven distribution of tension, causing premature failure and an inaccurate tension measurement. This problem will also occur if the paper is not positioned exactly perpendicular to the floor when hanging from the clamps.

The upper bar clamp is mounted in a bench vise as tightly as possible. It should hang over the edge of the bench so that buckets of sand can be suspended from the second clamp. A large catch bucket is placed under the suspended buckets in order to catch them and their contents when the strip breaks.

It is necessary to keep the bottom clamp balanced so that it does not bend the paper as the weight is increased. If the entire length of the paper strip is not kept in a straight line then you will be measuring some combination of tensile strength and shear strength when it fails, giving you a number that is lower than the actual tensile strength. Thus, two buckets are used to balance the clamp, as seen in Figure 1.

Sand is slowly introduced into each bucket, alternating between the two in order to keep the bottom clamp level. If you know it is going to take over 20lbs of sand to break the paper, you can start off with a 10lb dumbbell weight in the bottom of the bucket as shown in Figure one. When you start getting close to where you think the paper will break, slow down the rate of adding sand. Your anticipation of the break point will build to the point that you will jump and dump any sand in your scoop when the paper finally fails and the buckets crash to the floor.

When the paper breaks, simply weigh everything that fell into the bucket and record the number. Repeat the process for the second strip and use the following formula to compute the J value:

J = (T1 + T2)/2

Where T1 and T2 are the two weights you measured divided by the width of the paper strips.

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Strip Pasting Calculations for Paper Ball Shells...

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Test Results:
Several grades and weights of paper were used for conducting the tensile strength tests. The highest quality paper samples were obtained from PyroSupplies.com (www.pyrosupplies.com), a new online supplier to the pyrotechnics community that has managed to scour the planet for the best quality papers and string for making fireworks. These samples were contrasted by some very low quality recycled and grocery bag papers in order to demonstrate the amount of labor that can be saved by using good paper.

The results of three trials were averaged together for each type of paper. Each trial consisted of two tensile strength measurements, one for each grain orientation.

Table 1. Tensile Strength Measurements for Various Paper Samples.

Paper Type	Tensile Strength #1 (grain short)	Tensile Strength #2 (grain long)	J Value
70 lb Virgin Kraft (pyrosupplies.com)	23 lb/in	36 lb/in	29.5 lb/in 5.28 kg/cm
60 lb Virgin Kraft (pyrosupplies.com)	33 lb/in	28 lb/in	30.5 lb/in 5.46 kg/cm
60 lb Grocery Bag (Publix)	18 lb/in	20 lb/in	19 lb/in 3.40 kg/cm
60 lb Recycled Kraft (office supply store)	20 lb/in	29 lb/in	24.5 lb/in 4.38 kg/cm
40 lb Natural MGB Virgin Kraft (pyrosupplies.com)	15 lb/in	25 lb/in	20 lb/in 3.58 kg/cm

Plugging the numbers from Table 1 into Shimizu's formula gives the results below. The diameters used in the calculations were those of standard Chinese strawboard hemispheres. No layer counts are given for combinations where the paper would be too thick or too thin for pasting the given shell size.

Table 2. Paste Layer Requirements for Common Shell Sizes.

Paper Type	3"	4"	5"	6"	8"	10"	12"
Hemisphere O.D.	2-3/8"	3-3/8"	4-3/8"	5-3/8"	7-1/4"	9-1/8"	10-3/4"
70 lb Virgin Kraft (pyrosupplies.com)	X	X	X	14	20	25	29
60 lb Virgin Kraft (pyrosupplies.com)	X	X	11	14	19	24	28

60 lb Grocery Bag (Publix)	X	X	18	22	30	38	45
60 lb Recycled Kraft (office supply store)	X	X	14	17	24	30	35
40 lb Natural MGB (pyrosupplies.com)	9	13	17	X	X	X	X

While recycled kraft paper lays down against the shell easier when pasting, it also tears easier during manipulation and, as this table shows, can result in more than 30% more layers to achieve the same strength as a high quality virgin kraft paper. The extra work might not seem like much for a small shell, but can add up to several additional hours when making a 10" or 12" shell.

Depending on the type of burst charge used and the strength of your paste, you may find that you can use a few less layers than shown here and still get good results. Keep in mind that many pasting methods where the strips overlap result in two actual layers of paper each time the pattern is worked one turn around the shell. Thus the application of 14 layers only seems like 7 layers when applied. Also note that odd numbered layer requirements must be rounded up one layer if your paste method results in two layers per round.

Related Articles:

[Strip Pasting Methods]
[6" Double Petal Round Shell]
[6" Ring and Bow Tie Shell]

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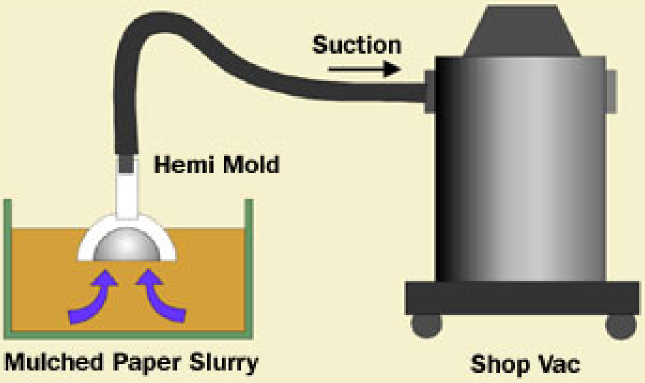
Technique...

Making Vacu-Form Hemispheres



January, 2002 Issue

Letter from the Editor

Technique:
Making Vacu-form Hemispheres.

Build This:
6" Ring and Bow Tie Shell.

Tool Tip:
Coating Rice Hulls in a Star Roller.

Gallery:
Florida Fall Fireworks Festival 2001

Summary:

This method of producing home-made paper hemispheres for use in making round shells represents a breakthrough in the quest for affordable hemispheres for the pyro hobbyist. The method was adapted from methods employed by the commercial paper recycling industry and brought to the pyro world for the first time by Octavio Aguiar of the Florida Pyrotechnics Arts Guild in April of 2001.

Materials:

- Newspaper or low-grade recycled kraft
- 4,6,8 & 10 inch plastic shell hemi, female side
- One foot lengths of 1-1/2" PVC pipe
- Fiberglass cloth
- Epoxy & epoxy thickener (microfibers, sawdust etc)
- 10 inch square sheet of 1/8" plastic (acrylic, plexiglass etc.)
- Paraffin or mold release
- Spandex or Lycra material
- 1/8" elastic bands
- 4 inch dia. rubber ball

Tools:

- Shop Vac
- Blender
- Drying frames
- Small Dremel type hobby drill
- 1/16" drill bit
- 1 inch disposable brushes
- Latex Gloves

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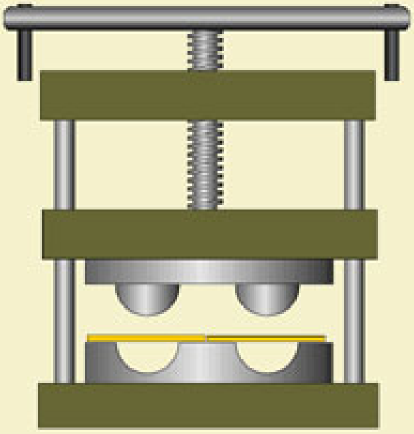

Figure 1: Flywheel type hemi press.

Methods of Hemisphere Construction:
There are currently three general methods of constructing paper hemispheres for use in making round shells. The most common method used in industry is to press a stack of special "daisy" shaped disks into a mold under high pressure. Both Chinese and Japanese hemispheres are made in this way, although the latter are generally of higher quality. The chinese often use a manually operated flywheel type press as shown in Figure one, which can gang-press four or more hemispheres at a time.

The second method, used mainly by hobbyists building small quantities of shells, involves pasting layers of paper over a wax coated ball, then cutting the paper along the equator and removing the two hemispheres from the ball when dry. While this does result in nice, smooth hemispheres, this method has the disadvantage being quite time consuming and requires a seperate mold for each hemi to be made in one sitting.

The third method, least known and barely used until recently, involves the use of paper mulch. First investigated by Dave Allen in the early 90's, a method was devised where newspaper was soaked in water, blended into pulp, formed into a thin sheet and then pressed over a ball shaped mold. However, this method also suffered from the need for a seperate mold for each hemi to be formed, and the finished hemispheres had problems with wrinkles where the excess paper bunched up around the edges.

A second attempt at making paper mulch hemispheres was made a few years later by Phil Martinez using shredded paper insulation. The paper was blended with dextrin, bentonite and wheat paste, then pressed between a male and female mold. Due to the inconsistencies in wall thickness of the finished hemispheres, along with the need for properly dimensioned male and female molds, the method never really caught on.

It was not until ten years later that Octavio Aguiar finally solved the challange of making acceptable hemispheres in a timely fashion from paper mulch. At the time of this writing, over a hundred shells have been built and tested using the methods described here, many of them winning first place in various competitions. There is no question that the method produces shells that function every bit as good as those using commercial hemispheres. While constructing the various sized molds involves a bit of work, it is not beyond the capabilities of the average pyro who has fabricated such things as ball mills, wooden tooling etc. All parts are available off the shelf in local retail stores, making for a good weekend project.

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Constructing the Mold:
While the method of making vacu-form hemispheres is quite simple, building the mold will probably be the sticking point for most people. The basic mold consists of an outer casing with a nested casing of the desired hemi size inside of it, as shown in Figure 2. The inner hemi is held in place by a retainer ring, which must be cut from a sheet of thin material such that the O.D. of the ring fits just inside the outer casing and the I.D. of the ring equals the O.D. of the inner hemisphere. A piece of PVC pipe modified to fit your shop vac hose is glued to the bottom of the outer casing.

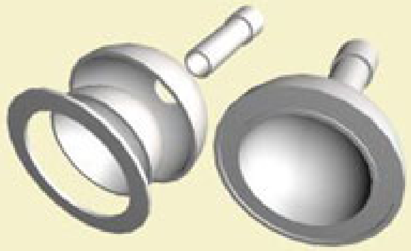

Figure 2: Mold made from plastic shell hemis, PVC and a plastic ring.

The difference in diameter between the outer casing and the inner casing should be about two inches, which will leave a one inch flange around the hemispheres as they are ejected from the mold. This flange serves to strengthen the wet hemi after it is ejected onto a screen for drying, and help maintain roundness as the paper shrinks upon drying. The flange is later cut off with scissors when the hemi is fully dried.

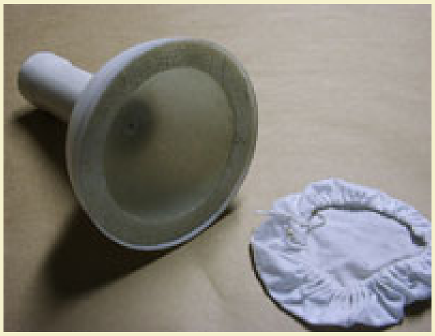

Figure 3: A 6" fiberglass mold with spandex filter cap.

Making Plastic Molds:
The simpelest way to make a mold is to use two plastic hemispheres used to make plastic ball shells. A four inch mold would have a four inch hemi nested inside a six inch hemi. A six inch mold would have a six inch hemi nested inside an eight inch hemi. The inner hemi should be the male half, so that there is no notch inside the inner lip. The outer hemi should be the female half, so that the notch inside the lip serves to support the retainer ring.

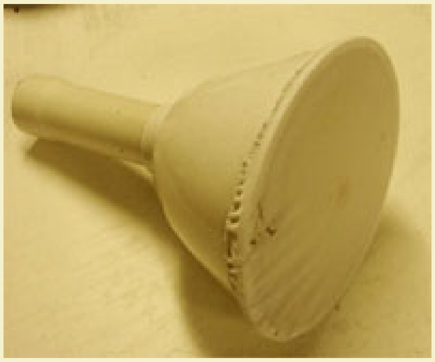

Figure 4: An 8" mold with filter cap in place. Outer casing was made from a flower pot.

Fabricating the ring is the tricky part of building the molds. If you are familiar with using a router table to cut circles with a pin jig, then the job is an easy one. However, most people probably do not have such a setup and will have to use hand tools such as a coping saw or a metal nibbler tool. The material used for the ring should not be too thick or it will create a dead zone for suction around the lip of the mold. A 1/16" thick acrylic sheet works well, as does formica counter top material.

Once the ring is made, it must be glued to the inner plastic hemi with epoxy or other strong adhesive. The joint must be able to withstand repeated pressing against the inside of the mold when making the hemis. If there is any kind of time fuse nipple on the plastic hemi, it should be shaved off. Hemis where the time fuse hole is already bored through the case should not be used, but may work if nothing else is available. The hole will cause a nipple to be formed on the paper hemi after it is formed.

With the ring glued in place, the entire inner piece must be drilled full of small holes as densely as possible. Holes ranging from 1/32" to 5/64" will work, with the larger hole saving some time spent drilling. It is easiest to use a small Dremel tool for this task, preferably with a low speed setting to keep

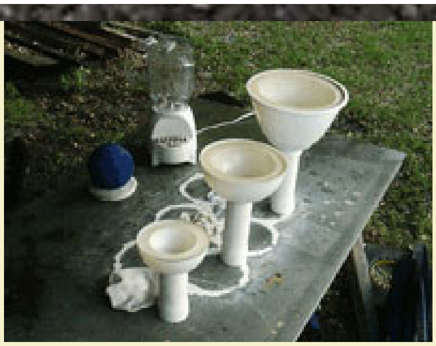

Figure 5: A set of 4", 6" and 8" molds.

from melting the plastic and guming up the drill bit. Start at the top of the hemi and work down the sides, keeping the holes about 1/8" on center and spaced evenly from each other. Clamping a small piece of wood so that it extends beyond the edge of the table makes a good resting fixture for holding the hemi while drilling the holes in the sides. The flange must also be drilled out in the same way. For a six inch mold, the drilling process can take several hours, but once it's done the hard part is over.

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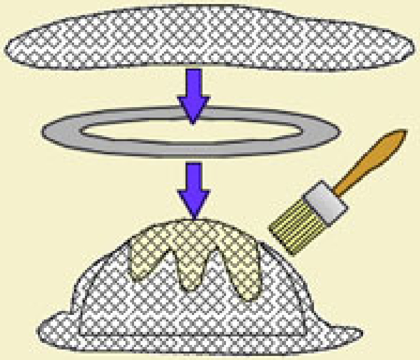

Figure 6: Applying fiberglass over plastic hemi.

Making Fiberglass Molds:

While making the inner part of the mold using plastic shell hemispheres is the quickest and easiest way to get the job done, it has the disadvantage of creating hemispheres that are slightly undersized. Due to the fact that the paper mulch will shrink as it dries, the mold has to be slightly larger than the desired size of the finished hemisphere. In the case of six inch hemispheres, the hemi will lose about 1/4" inch of its diameter as it dries, resulting in a hemi that is about 5-1/8" O.D. After a 1/8" thick paste layer has been applied, the final shell O.D. will only be 5-3/8", resulting in a rather lose fit in the average 6" mortar.

In order to create a standard commercial sized 6" hemi, a larger mold can be made by fiber glassing over the outside of a 6" plastic hemi, then removing the mold. The extra work created by the fiberglass step is more than compensated by the fact that drilling the holes through the fiberglass goes twice as fast as drilling through the plastic. Another advantage is the fact that the ring can be more securely fastened by sandwiching it between fiberglass layers when making the mold.

The first step in making the fiberglass type mold is to coat the hemisphere to be molded over with a non-stick substance such as paraffin or mold release. The mold will still be difficult to remove when it dries, but would be impossible otherwise. A heat gun can be of use when distributing paraffin over the surface of the plastic hemi.

Next the prepared hemi is placed on a sheet of wax paper and a sheet of fiberglass cloth placed over it such that the cloth extends beyond the edges of the hemi by over an inch. A high quality marine epoxy such as West System or MAS is then used to wet down the cloth so that it is spread evenly across the surface of the hemi with no air bubbles or wrinkles. The cloth should form a flange around the edge of the hemi, such that it lays out flat on the wax paper.

After the first layer of glass cloth is wetted out, the retainer ring is pressed down over the hemi so that it fits snug around the rim, resting on top of the fiberglass flange. A second sheet of glass cloth is then placed over the assembly and wetted out as before. This effectively sandwiches the retainer ring between two layers of fiberglass. The cloth will want to pull away from the rim where the ring meets the hemi wall, creating an air pocket. Some vigilance is required to keep working this problem area until there are no air bubbles and the epoxy sets enough to prevent the cloth from sliding out of position.

The epoxy should be allowed to set up to the point that it is almost dry but still slightly pliable. Usually about eight hours, depending on the temperature. The plastic hemisphere will be quite difficult to remove regardless of how it was prepped, and the fiberglass mold will usually get turned inside out during the process. Use a small knife to pry around the edges of the mold and separate it from the plastic hemi. As you work the flange end free, it becomes necessary to actually force the mold to fold over itself as if taking off a sock. This will produce some stress marks in the epoxy, but will not effect the shape of the final mold. Once about half the mold has been pried off it should be possible to extract the plastic hemi by force. The deformed mold can now be popped back into position and smoothed out. The mold is then allowed to fully cure before drilling.

Drilling out the fiberglass mold will go much quicker than the plastic mold, as the fiberglass turns to dust and there is no problem with the drill bit clogging. Holes can be made almost as fast as you can move the drill, but care must be taken not to dwell on each hole too long or the bit will easily side cut the hole and make it larger.

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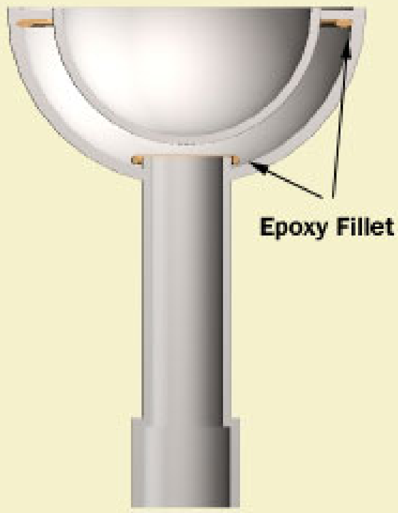

Figure 7: Attachment of mold components.

Finishing the Mold:
Before the drilled out "screen" part of the mold is glued to the inside of the outer shell, the suction pipe must be glued into place. This pipe is a piece of PVC that is sized according to what will attach to your shop vac. Shop vac hoses vary in size, so you will have to find what works best. In the event that your vac hose does not fit inside any standard sized PVC pipe, as is the case with Craftsman hoses, a slip coupling can be created by heating one end of the PVC pipe with a heat gun until it becomes pliable, then forcing the vac hose into the pipe. The PVC will stretch around the vac hose once it is hot, then it is allowed to cool with the vac hose inside. Once cooled off, the PVC will retain the new shape and your hose will now fit snugly into the socket.

A hole is now cut into the bottom of the mold so that the pipe fits inside. This can be a tricky hole to cut in the bottom of a plastic hemi, but a Dremel with a tile cutting bit will do the job. A serrated hobby knife may also do the trick. Place the pipe on the hemi and trace around its diameter to get the hole's outline.

With the hole cut out, the pipe is inserted so that 1/4" protrudes beyond the inside wall of the hemi, then a bead of thickened epoxy is run around the inside seam to hold it in place.

Once the epoxy cures and the pipe is securely in place, another bead of epoxy or liquid nails is run around the lip of the case where the perforated screen will sit. When setting the inner screen into the adhesive, be careful not to allow any holes to become clogged with epoxy. The finished mold should look like Figure 7.

Making the Filter Cap:
In order to prevent the paper mulch from being sucked through the holes in the screen and clogging it up, a cloth barrier is placed between the screen and the mulch. The material used for this cloth should be capable of stretching in both directions, such as spandex or lycra material. The percentage of spandex can be as low as 10% and still be flexible enough to work.

A circle of the material is cut about four inches larger than the diameter of the mold it is to fit over. A 3/8" hem is then sewn into the edge of this circular piece in order to hold an elastic band. The band is threaded through the hem after it is completed by attaching a small safety pin to the tip of the elastic band and working it through a small break in the hem. The elastic is drawn until the desired tension is achieved, then tied off in a knot. The filter should be able to fit over the mold without sliding off when the material is stretched all the way down into the bottom of the cavity.

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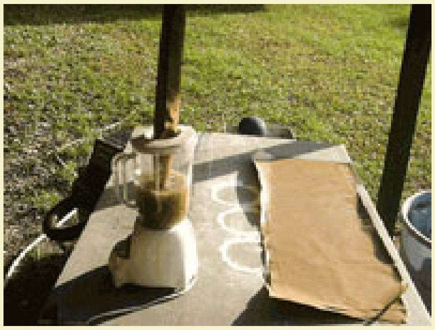

Figure 8: Mulching recycled kraft in a blender.

Setting Up the System:

Once you have your mold completed, you are ready to go into production. The only other things you will need are the shop vac, blender, a small rubber ball a few inches less in diameter than the hemi mold and a mulch tank that holds five gallons or more (plastic Rubber Maid storage boxes work great). Drying screens will also accelerate the the drying process, but are not totally necessary.

Due to the volumes of mulch that must be pulverized, the larger the blender you have the better. The one pictured in Figure 8 has a 9 cup capacity, which must be loaded twelve times to make a five gallon batch of mulch. This is the bottleneck of the process, which could be vastly improved with an industrial blender if the cost were not prohibitive.

The shop vac should be the wet-dry variety with a dust filter that removes when used to suck up water. The one used in this process is a 3.5 HP Craftsman model, but smaller ones will probably work as well.

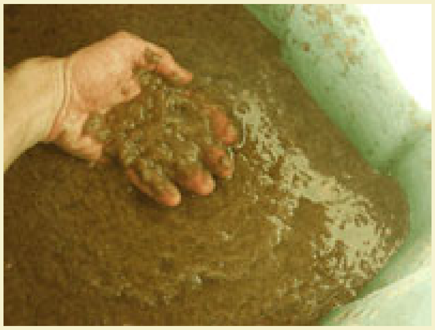

Figure 9: Mulched paper diluted with water.

Preparing the Mulch:

The original mulch composition specified by Octavio consisted of a blend of newspaper and recycled kraft in a ratio of 50:50. While using 100% newspaper also works, the added kraft paper makes the finished hemi stiffer and stronger. The tensile strength of these hemis are so weak that no matter what you use it will have no effect on the break, but a hemi that tears too easily can rip at the edges when compacting two fully loaded hemis together. Paper manufactures suggest adding starch to the mulch in order to strengthen the final product.

The mulch I have adapted for this process uses 100% recycled kraft with wheat paste as the stiffener. The kraft is a very poor quality recycled variety available in most home improvement centers as "builders paper." The low wet strength of this paper is ideal for blending it into mulch, as virgin kraft would be very difficult to mulch. The paper is also cheap, at around $7.00 for a 130 foot roll. One roll will make about 75 sets of six inch hemispheres, resulting in a cost of about 11 cents per shell (compared to $2.50 for imported hemis).

Start by cutting twelve strips from the roll, each measuring a foot wide by three feet long. These strips are then stacked up, folded in half and submerged in water until they are completely soaked. This type of paper also absorbs water very fast, so you need not wait long.

The soaked stack of paper is now laid out on a table next to the blender, as shown in Figure 8. The process is best done outdoors with a garden sprayer close at hand, as it is messy and requires lots of water. The blender is first filled with about 5 cups of water, then run at its highest setting. A single paper strip is rolled up length wise and fed in through the hole in the top of the blender lid as shown in figure 8. The feed rate should be slow so that excessive stress is not placed on the blender motor. Allow the blender to run a few seconds after the entire roll has been chewed up, perhaps rolling the next sheet while you wait.

This process is repeated for each of the twelve strips, each time dumping the mulched contents into your mulch tank and refilling the blender with water. When all the strips are blended, add three cups of water and blend in wheat gluten (the wallpaper type) until it is so thick that it no longer can spin fast enough to create a vortex. This paste mixture is then added to the mulch tank with the rest of the brown paper mulch. The mixture is finally diluted with water until you have about four or five gallons. The consistency should be fairly thick, but there is no exact amount required. If the mixture is too thin, then the mold will have to be submerged longer, while having it too thick will result in big globs stuck to the mold when it is removed. Cupping a hand full of mulch should retain the amount of paper shown in Figure 9.

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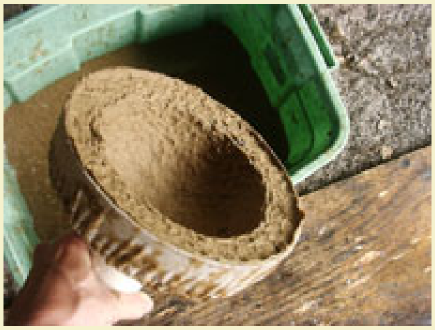

Figure 10: Removing loaded mold from tank.

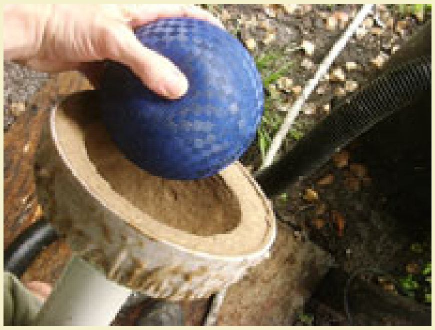

Figure 11: Flattening mulch with rubber ball.

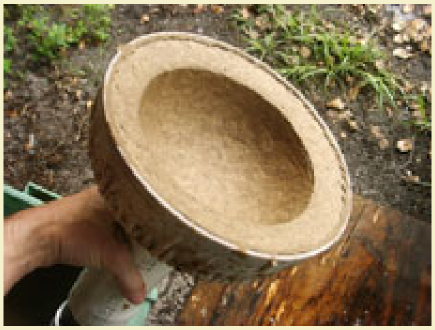

Figure 12: Flattened mulch ready for removal.

Drawing Hemis from the Mulch Tank:
With your tank of mulch completed, you are now ready for the fun part. Make sure you have enough screens or trays to store all the hemis that can be made from your entire batch of mulch, as the wheat paste component will prevent you from being able to store the mulch very long without it going sour. You must also remember to dump the water from your shop vac immediately when finished, or it will sour with a foul smell after a day or two.

With the filter cap on the mold and the mold attached to the shop vac hose, power up the vac and submerge the mold into the mulch. Slowly move the mold up and down for about six seconds, then remove it and quickly observe the amount of mulch that has stuck to the mold. Once the mold is removed, it can not be resubmerged to pick up additional mulch, as it immediately flattens out and blocks further passage of water. The amount of mulch extracted can vary, but it is good to error on the thick side. The proper amount should look like Figure 10. A bit of practice will be required in order to get the feel for how long to submerge the mold and how much extracted mulch is enough. Bad or damaged hemis can be scooped out of the mold and returned to the tank, where they dissolve back in with the rest of the mulch. This allows lots of practice without actually wasting any material.

Once the mold is removed from the tank, it will immediately begin to flatten to the state shown in Figure 10. This process can be accelerated by holding the mold up high so that the water trapped in the low point of the hose is emptied into the shop vac tank. Once the excess water has been removed, the mulch will still have irregularities in the surface. These should be smoothed down by using a rubber ball small enough to fit into the mold cavity, as shown in Figure 11. Rolling the ball around while pressing down on it should create the results shown in Figure 12.

At this point the hemi is ready to be ejected from the mold. This is the stage that will likely give people the most problems, as doing it incorrectly will damage the fragile hemi. The trick is to turn off the shop vac, remove the mold from the hose and get it positioned a few inches above your drying screen as fast as possible. Depending on how smooth your filter cap material is, the mold may even eject by itself. If not, you will have to blow into the suction pipe to force the hemi out of the mold. Ideally, the hemi should drop to the screen as the mold is slowly pulled away from it.

There are several problems that can occur at this stage of the process, and you will likely have to scrap the first five or more attempts back into the mulch bucket until you can get the hang of it. A trouble shooting chart has been provided at the end of this article for tips on how to correct defects that may occur.

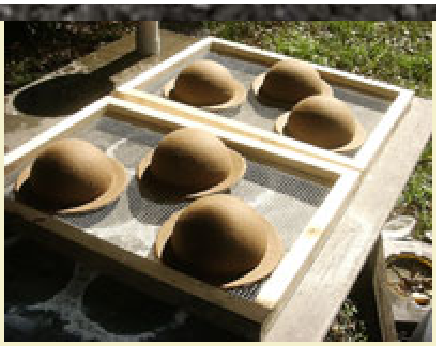

Figure 13: Six inch hemis ready for drying.

It is important that the finished hemispheres are round and smooth as shown in Figure 13. Any wrinkles in the surface will become greatly amplified as the hemi dries. Even the smoothest hemispheres will develop a rough textured surface due to the shrinkage when drying, but wrinkles that appear when the hemi is still wet will result in overly ragged hemispheres when dry. Such a defect will show through the pasted paper of the finished shell, making it unattractive and possibly even effecting the break.

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Volume 2, Issue 1

Making Vacu-Form Hemispheres...

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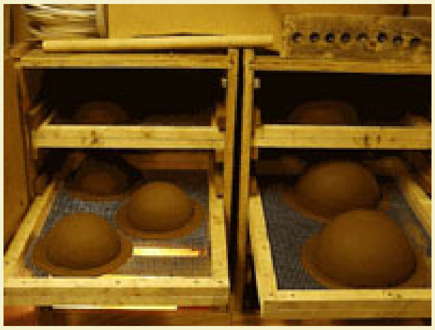

Figure 14: Assorted hemis drying in a dehumidified dry-box with circulated air.

Finishing the Hemispheres:

The hemispheres are very fragile in their wet state, and there is no way to effectively smooth out dents if you accidentally push your finger into one. It is best to place them in a safe place and get them dry as fast as possible. An enclosed drying box as shown in Figure 14 will not only protect them from accidental damage, but the dry circulated air will dry a full load in just 24 hours. The hemis may also be placed out in the sun for drying, turning them over once the outside is dry.

After they are dry, the excess flange around the rim is cut off with a pair of sharp scissors as shown in Figure 15. The circular scraps of flange may be collected over time and then recycled back into mulch using the blender.

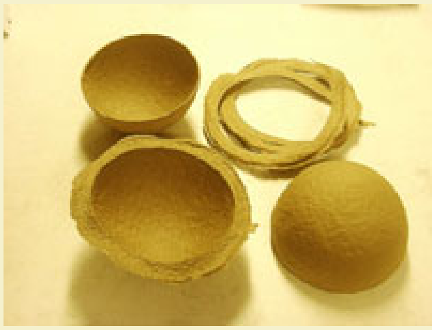

Figure 15: Cutting the flange off of dried hemis.

For a perfectly flat edge that shows no gaps when the hemi sets are put together, a disk sander can be used to level them off as shown in Figure 16. The hemi must be held exactly at the center of rotation to keep from being thrown by the sander.

Due to slight differences in the thickness of each hemi, it is often necessary to pair them up to find sets that fit each other the best. They can then be numbered and stored in a stack, as shown in Figure 17.

Using Vacu-Form Hemispheres:

One disadvantage to the recycled paper material is it's high absorption rate. The hemi must be essentially waterproofed on the outside prior to pasting, otherwise the water from the paste will quickly absorb into the hemi, making them soggy and easily deformable.

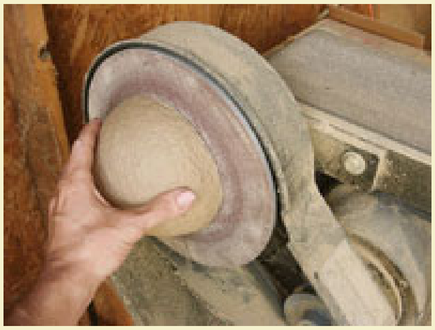

Figure 16: Cleaning up the edges on a disk sander.

Some people prefer to spray paint the hemis with a varnish or shellac based paint prior to fusing and assembly. Another method is to apply a single layer of masking tape strips over the shell after it has been loaded and assembled. Either method is effective for preventing the absorption problem, and also decreases the amount of time required for the shell to dry.

Advantages of Vacu-Form Hemispheres:

There are a few advantages when using this type of hemisphere over commercial hemispheres. Due to the low density of the paper, there is very little tensile strength relative to the outer paste layer. This means that the hemi has no effect on the containment of the shell during the burst, which is actually a desirable characteristic. You will not find shell fragments from a ball shell made with vacu-form hemispheres where the casing broke on a flat line at the hemisphere junction as you often do with the stronger commercial hemispheres. Shell fragments are often very small, with the inner hemi material not even attached to the pasted paper.

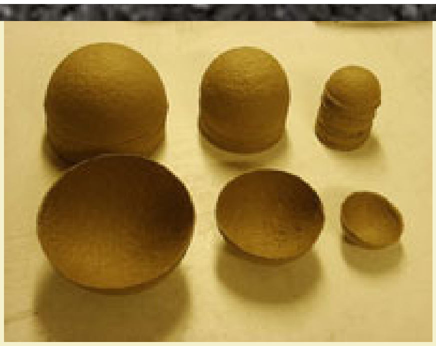

Figure 17: Completed sets of 8", 6" and 4" hemispheres.

Another advantage is in the application of ring shells of the type where the ring stars are hot glued to the hemi wall. The hemi material is very flakey, allowing the star to easily rip free of the casing upon burst instead of clustering together on a fragment for a few thousandths of a second before burning free, resulting in an imperfection in the ring pattern.

More...

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Making Vacu-Form Hemispheres...

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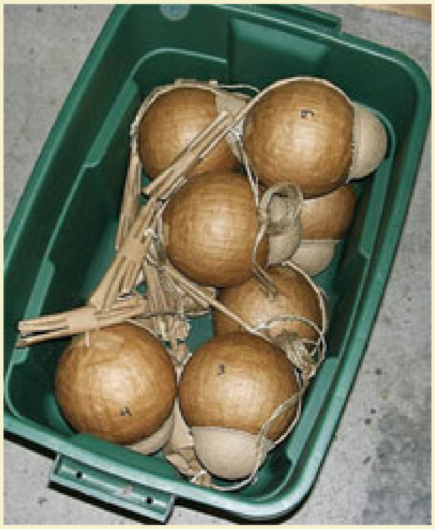

Figure 18: Finished shells utilizing vacu-form hemispheres. Note the vacu-form lift cups.

Other Uses for Vacu-Forms:
While vacu-form technology is easily suited to making hemispheres for round shells, there are other areas where it can also prove useful. A four inch hemi that is trimmed with a small amount of the flange left in place makes a perfect lift cup for six inch shells. The sturdy cup is much less susceptible to lingering sparks burning through it when dropped in a hot mortar, compared to the few layers of paper traditionally pasted over the lift bag in round shells.

Thin four inch hemis also make ideal containment hemis for the inner petal of six inch double petal shells. The soft paper can easily be vented with an awl for flame propagation purposes, compared to drilling out commercial paper or plastic hemis when venting inner petal hemis. Likewise, six inch hemis can be used inside eight and twelve inch shells.

Further development can lead to multiple molds capable of casting more than one hemi at a time. It may even be possible to attach four separate six inch hemi molds together using PVC pipe fittings on the suction stem, allowing faster production.

When Mr. Aguiar originally approached commercial manufactures of recycled paper products to have them make hemispheres for the hobby industry, they planned to use 3 by 8 foot frames with 75 six inch hemi molds each. The entire cycle for such commercial operations was about 45 seconds per frame set-- 10 seconds submerged in the pulp, followed by a 20 second drying period before being blown off the frame. The estimated production was 4500 per hour, resulting in a cost of 5 cents per piece!

Until demands warrant the initial investment in making commercially produced recycled paper products available for the fireworks industry, those hobbyists wishing to tinker with the technology can do so with minimal costs and tooling.

Trouble Shooting Guide

Problem	Probable Cause
Top of hemi has wrinkles.	Blowing out mold too close to the screen. Filter cloth too tight. Hemi too thin, submerge for longer period to acquire more mulch.
Hemi too thin around bottom edge.	Not enough holes drilled around flange seam joint, try drilling at an angle to vent dead space where the ring connects.
Hemi not ejecting from mold.	Clean filter cloth between each hemi. Try smoother material for filter cloth. Blow into suction pipe.

Hemi collapses after ejecting onto screen, or bottom edge compresses right above the flange.	Ejecting from too high above screen. Crushing it by moving mold downward while blowing out. Hemi too thin, submerge for longer period to acquire more mulch.
Mold will not pick up enough mulch.	Mulch too thin, too much water was added. Too much wheat paste was added. Mulch not deep enough, transfer to a smaller container. Shop vac doesn't have enough suction.
Hemi too thick.	Process consumes more water than mulch, so more water must be occasionally added to the mulch tank. Submerge for shorter time period.
Hemi ejects before mold can be positioned over screen.	Filter cloth is too tight or too smooth. Try placing an inflated balloon into the cavity and removig the hemi onto the balloon, then transferring it from the balloon to the screen.

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Volume 4, Issue 2

Vacu-Form Molding Tips

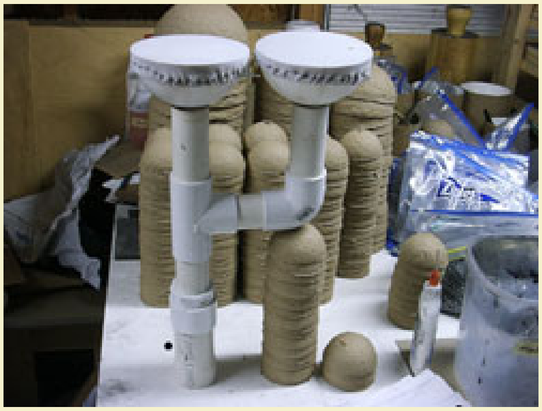

Figure 1: Multi-mold for producing two 4" hemis at once.

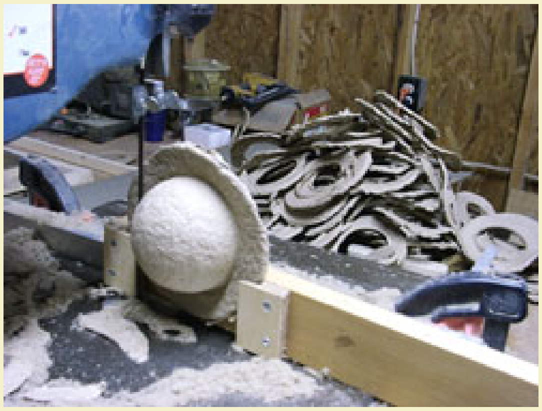

Figure 2: Fixture for triming off hemi flange using a band saw.

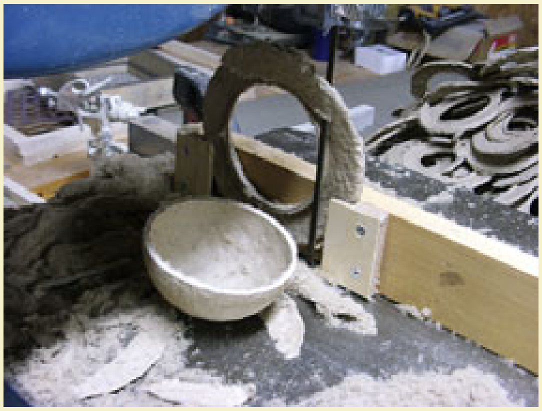

Figure 3: Wooden push stick keeps hands

Introduction:
When Octavio Aguiar first demonstrated the method of making vacu-form shell casings back in April of 2001, I thought the pyro community would be quick to adopt it. Three years later it appears that there really aren't that many people making shell casings in this way, probably due to the fact that most hobbyists tend to build plastic shells instead. For those that are interested in paper shells, there are a few barriers to entry that may keep people from trying the vacu-form method-- mainly the task of building the mold and perhaps also the perception that this is a lot of work to go through to make hemis.

This article presents a collection of improvements to the original process that make it faster, along with some ideas to help in making your own molds.

Multi-Molds:
The most obvious way to decrease the time spent pumping out molds is to pump more than one at a time. Adding a second mold to a single-mold using PVC pipe as shown in Figure 1 will literally cut your time in half. For molds over 3" in size, it becomes impractical to build multi-mold plates as shown in this months Tool Tip. Using pipe fittings to join separate molds is actually easier in this case, and they work just as well. The dual 4" mold shown in Figure 1 was used to produce the 100 sets of kraft hemis behind it in about 3 hours.

Trimming Molds:
One of the more time consuming processes is trimming the excess flange around the rim of the mold. The blisters and sore hands that would result in trimming the 200 hemis shown in Figure 1 would be prohibitive. However, the simple jig shown in Figure 2 allowed all 200 hemis to be trimmed in about an hour using a band saw. The hemi is slipped on edge into a wooden push stick that is slid into the blade with a fence guide behind it. The hemi is clean cut and requires no further sanding, as seen in Figure 3. The cutoff flanges are saved and recycled back into mulch for making still more hemis. The ten

away from blade while trimming.

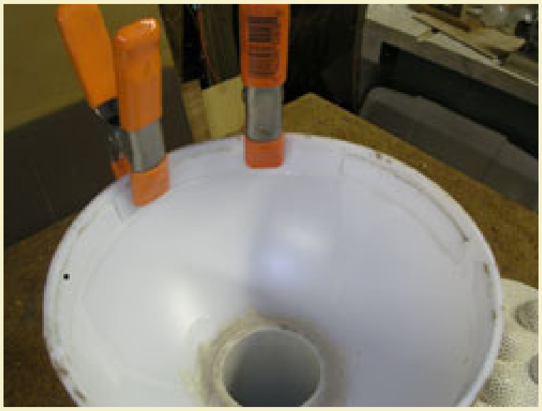

Figure 4: Converting an 8" male hemi into a female hemi.

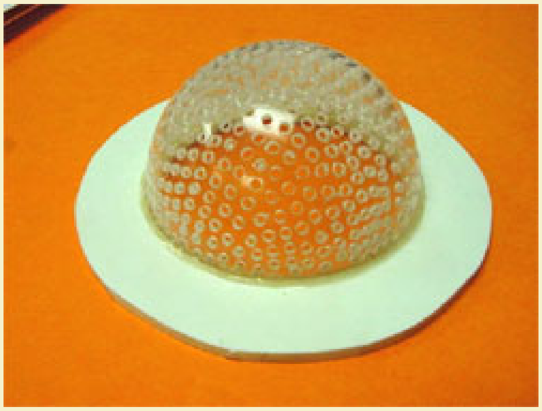

Figure 5: 3" mold made from store-bought Christmas tree ornament.

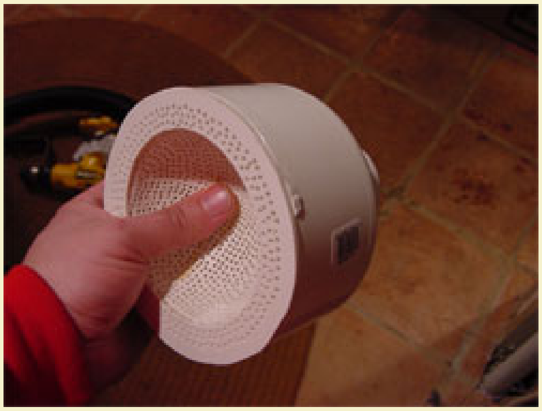

Figure 6: PVC endcap used to house a 4" mold.

sets of 8" hemis shown in Figure 1 were made from the flange cutoffs resulting from the 200 4" hemis!

Converting 8" Hemis:
The plastic shell casings make excellent housings for your molds, but only the "female" side that contains the inner ledge to support the mold plates are desirable. Rather than dispose of the other "male" hemi, simply give it a "sex change" by gluing a ledge inside of it using cut up pieces from another plastic shell. Glue made from 50/50 acetone/xylene is painted onto the inside lip of the shell and the pieces to be clamped, then held in place using spring clamps as seen in Figure 4.

Pre-made Molds:
Rather than make your own mold using fiberglass or melted plastic, another option is to find plastic hemis that are already the correct size and drill them full of holes. Figure 5 shows a 3" mold made from plastic Christmas tree ornaments that are sold in hobby-craft supply stores such as Michaels. These are actually clear plastic hemis that come apart at the center just like a plastic ball shell. In a pinch you could probably use one of these store bought "shells" to build a plastic ball shell, with the unique feature of being able to see the contents of the shell after it has already been loaded and closed!

Mold Casings:
While plastic shell casings make great mold housings, there are a variety of things that can work well. Flower pots, bowls or anything with an inner ledge that can be used to support your mold plate against the strong suction forces that will be pulling on it. Figure 6 shows a PVC end cap being used as a mold casing for a 4" mold. The back side of the PVC cap was drilled out and fitted with a PVC coupler that connects to the shop vac hose. Since the mold in this example was also made from PVC, the entire assembly could be strongly held together using only PVC cement.

Removing the Blender Process:
One of the biggest bottlenecks of making vacu-form hemis is the mulching of the paper. Cutting and blending the paper accounts for 50% of the process time, and even when alternating between two blenders it is still hard on the motors and blades.

A common product found in many hardware stores is a type of insulation called "blown-in" insulation. This is nothing more than shredded newspaper that has been vacuum packed into large bales, as seen in Figure 7. A 22lb bale of this pre-shredded paper costs about $7, and a single pound of the material will yield about a 15 gallon batch of mulch. Simply add one pound of dry insulation to a 15 gallon bucket, fill it up with water and then add 4 cups of wheat paste.

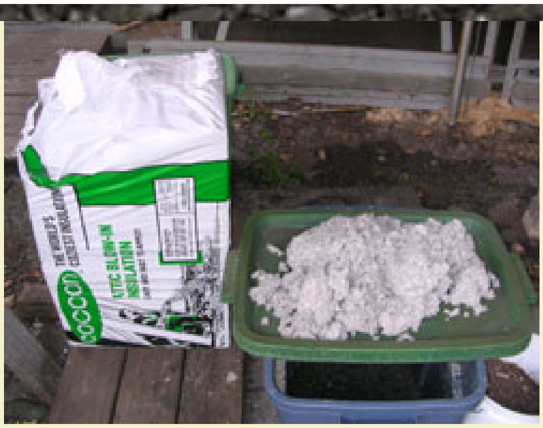

Figure 7: Blown-in insulation eliminates the blender process for making the paper mulch.

This type of mulch tends to draw out thicker on your mold and requires more work to flatten out, also resulting in slightly thicker hemis. It will work fine for shells 3" and above, but is not recommended for very small shells due to the space consumed by the thicker walls. Insulation mulch does eject easier from the mold however, and for some reason the outer surface does not get rough and wrinkled the way kraft hemis do. The nature of the fibers allows the shells to dry just as smooth as when they were wet, and the shrinkage is just the same as for kraft.

Another option is to mix the insulation mulch with kraft mulch in a 50-50 ratio, which produces a shell casing more like the 100% kraft variety while still saving you some time with the blender. These 50/50 hemis also have the advantage of finishing smoother than the 100% kraft versions.

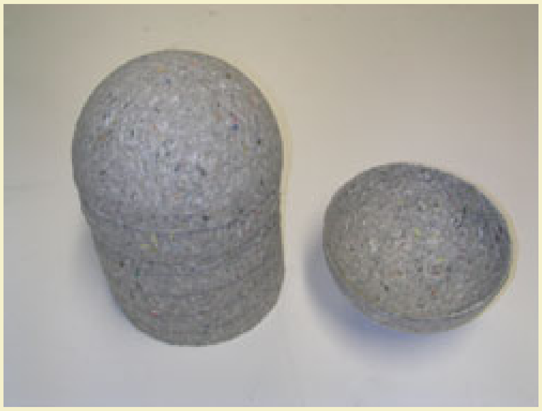

Figure 8: 6" hemis made from the shreaded newspaper insulation.

A 100% insulation hemi is not quite as strong as a 100% kraft hemi, but they are plenty sturdy and will work just fine for building shells. Figure 8 shows a batch of eight 6" hemis, cranked out in about 15 minutes and dried in one day. One 22 lb bag of insulation will produce 265 of these hemis, enough to make 132 shells! If you reprocess the flange cutoffs, you will be able to get up to 342 hemis from one bag (171 shells). If you were producing 8" hemis, one bag of insulation would give you 214 of them. Compare the $7 for one bag of insulation to the $396 you would spend on 132 6" paper hemi sets ($3/set), or $834 on 107 8" hemi sets ($7.80/set)!

How Large Can We Go?

I have made vacu-form hemis up to 8" in size. While it may be possible to go beyond this, I know of nobody who has even tried it. With commercial paper 12" shell casings costing around $20 a set, and since plastic shells in this range do not exist, the desire for a cheap and easy way to make large shell casings definitely exists. Building the molds for such large casings would be a considerable task however, and there might be problems with the damp hemis caving in after being ejected when produced in such a large size. One solution could be to let the hemi dry on the mold former before removing it.

Large shell casings are the next direction for vacu-form development, and I hope the engineering types out there might find interest in pursuing this challenge.

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Volume 3, Issue 1

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Build This...

Color to Report Cake

Summary:
Cake items are the king of consumer fireworks, and you never really gain full appreciation for the incredible state of refinement the Chinese have taken cakes to until you try and make one yourself!

This introductory cake project shows the construction of a typical color to report repeater. Like a true cake, the tubes are bottom fused and bound into a single disposable block.

Color Formulas: Mag Red, Mag Green

Materials:

- (6) 6" square file folder sheets
- (6) 6"x4" 30 lb kraft sheets
- (24) 5/8" I.D. x 5" long tubes
- 20g star comp

Tools:

- Hot glue gun
- 1/2" rod
- 1/2" rammer
- 1/2" ramming base
- 5/8" rammer

Unmeasured Materials:
hot glue, 3Fg, meal, flash powder, thin black match, 1/8" visco, fire clay

January, 2003 Issue

Letter from the Editor:
Happy New Year!

Build This:
Color to Report Cake

Technique:
Making Chinese Fuse

Tool Tip:
Tricks of the Trade

Autopsy:
8" Ring Shell

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Color to Report Cake

Page 2

Introduction:
Cake items are deceptively laborious items to create, which could explain why so little is written about their construction. On the plus side, cakes require very little composition to produce while also providing a long effect duration compared with chemical hungry items such as aerial shells. They are ideal for the beginner with a low budget or limited shoot sites, since 100g batches of color comp can make several cakes and shooting them does not attract much attention in areas where class C items are already legal.

Cakes can range from simple arrays of single shot star guns to complex assortments containing timed volleys of whistles, shells, tourbillions and essentially anything that can be shot out of a tube. The limited space constraints and timing issues provide many challenges for the pyrotechnician to master, and attempting to make this type of device brings a new level of appreciation for the extreme level of refinement the Chinese have achieved in this area.

Hobbyists who specialize in this particular spectrum of pyro are often referred to as "micro guys," since they must create very tiny effects to fit in the small tubes cakes require. A few micro guys even go so far as decorating their cakes with authentic looking wrappers, complete with warning labels, directions and of course a Chinese sounding name!

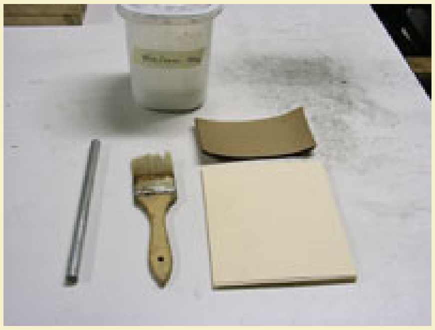

Figure 1: Materials for hand rolling tubes.

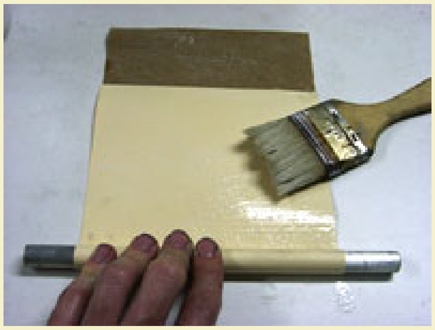

Figure 2: Applying diluted white glue to paper before rolling.

The construction method shown here is used in many common cake effects, so it is a good starting point for learning about basic cake construction. Many cake loads consist of a thin walled tube plugged at one end with a recessed clay plug, with a rising effect composition filling the recess and providing the timing. The tube can contain a report, breaks of colored stars, spinning effects, flying fish fuse or whistles to name a few. For this project the effect will be a colored rising comet to a report.

Making the Shot Tubes:
There are two tubes you will need to make this type of cake: the mortar and the shot. If you can buy both tubes in the size you need, then you can save yourself some work. But usually you have one tube on hand and must roll the other. I prefer to roll the shot to match whatever I have laying around for mortars, since the shot tube is smaller. I happen to have a very large supply of 6" long x 5/8" I.D. tubes that were given to me by a very generous passfire member, so I will use that as the mortar and design around it. The size is not critical, so feel free to adjust things to match what you have. If you make the shot exactly as shown here, you can shoot it out of tubes ranging from 5/8" to 3/4" I.D. with a length between 4" and 6". Shorter tubes will just require slightly more lift.

The shot tubes are 1-1/2" long with a 1/2" I.D. and an O.D. just under 5/8". I make these by first rolling 6" long tubes and then cutting them into four segments as seen in Figure 3. Each tube is rolled from a 6" square sheet of file folder paper, which makes very strong tubes that are also easy to roll. The first turn is wrapped around the former, as seen in Figure 2, then a mixture of white glue diluted 50% with water is brushed onto the remainder of the sheet and also on the small strip of 30 lb kraft that will make up the last few turns. The purpose of the thin kraft sheet is to keep the stiffer file folder paper from

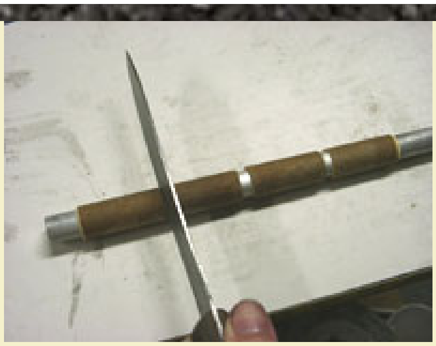

Figure 3: Cutting 6" tubes into 1-1/2" segments.

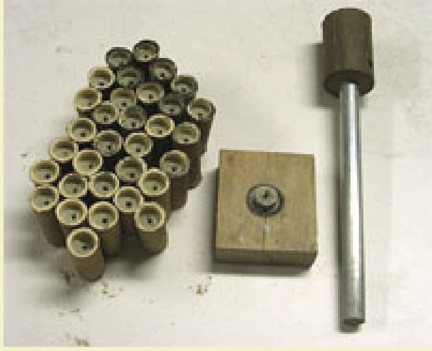

Figure 4: Clay plugs rammed and drilled.

unrolling once it is rolled.

Do not be tempted to use dry-rolled tubes for cake shots, as the lift pressure will blow the core through and telescope the case like a Chinese yo-yo! The layers of paper must be bound to each other to prevent this problem.

Cutting the tubes into segments while they are still on the former is the best way to get a nice clean edge, although it does tend to score up your rolling rod. Pressing down with a good sharp knife while moving it forward to spin the rod around should separate the tubes after about two complete turns.

You will need 24 shots to make this cake, but it is good to roll a few extra for tests. A food dehydrator can be used to accelerate the drying of these tubes, or even a wooden box heated with a 100W light bulb will do the trick.

Once the tubes are dry, you will need to ram a thin clay plug at the end of each one such that it is recessed from the end by 1/4". A block of wood with a segment of aluminum or wood dowel sticking out by 1/4" is required for making the plug, as seen in Figure 4. The plug only needs to be about 1/8" thick, and it does'nt need to be rammed as hard as a rocket or gerb nozzle would be.

Next you will need to drill a 1/8" passfire hole through all the plugs. You can fabricate your ramming base with a 1/8" pin and use a hollow drift if you want to form the hole and the plug in one operation. Make the pin at least 1/2" long if you go this route.

More...

Color to Report Cake

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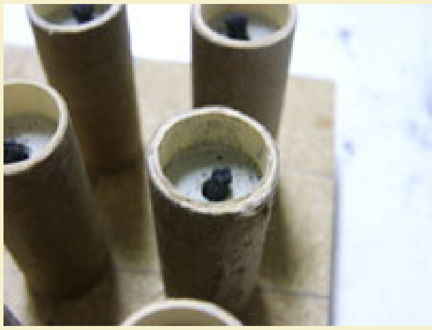

Figure 5: Chinese fuse inserted through passfire hole.

Loading the Shots:

The tricky part of getting these shots to function correctly is achieving a reliable passfire from the color rising effect into the contents of the tube. The Chinese typically use a double strand of the paper fuse described here, but I find this type of fuse to be unreliable when I make it myself. It will often fizzle out while making the transition through the clay plug. Small diameter black match of the type made for cross matching time fuse is my choice for this application. Not only is it easier and faster to make, it contains more powder and is thus less likely to lose fire.

If the stick of black match fits too tightly in the clay plug, it will be difficult to quickly assemble the shots and also cause a potential delay between the rising effect and the report. The hole in your clay plug should allow the match to easily drop through it without forcing it.

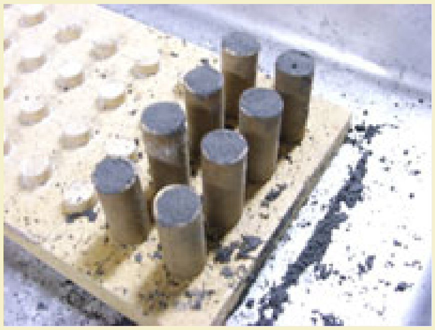

Figure 6: Damp color comp pressed into end cavity.

The problem with such a loose fitting piece of match is keeping it at the exact right height while loading the color composition into the cavity. The black match should only protrude a tiny amount above the clay plug, as seen in Figure 5. If it sticks up too far, or even protrudes all the way through the color comp, it will set of the salute too early while the color is still burning.

The easy solution to this problem is to load the shots on a wooden peg that acts as a depth stop for the pieces of match, as seen in Figure 6. Wooden dowels are glued into holes drilled in a sheet of particle board such that they stick up at least 1/2". It is important that they all be the same height, and also that your sticks of match all be cut to the same length. A good tool for reliably cutting all the black match pieces to the same length is described here.

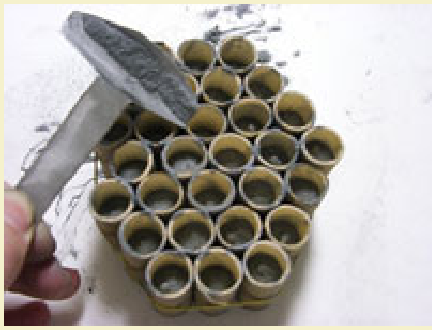

Figure 7: Loading flash into tubes with special scoop.

If you can not cut many pegs to the same length in order to make the jig shown in Figure 6, then just make one peg glued into a small block of wood and load each shot one at a time. Note that loading many at once with the multi-pin jig will save a considerable amount of time, so it is well worth making this jig if you plan to make many inserts of this type.

Once you have fabricated your fuse placement jig and inserted your black match sticks, dampen your color comp to the consistency of dough and press it into each cavity as shown in Figure 6. If you are using the mag colors suggested on page 1 of this article, adding 10 grams of water containing 15% alcohol to 20 grams of color composition will produce enough to load 24 shots. Note that dampening most other color comps with 50% water will over wet them, so you will have to determine the proper amount based on the formula you plan to use. The comp should be damp enough to seem like clay when it is pushed into the tubes, but not so damp that water oozes out when you press hard on the comp.

At this point I like to allow the color comp to fully dry before proceeding further. This can take at least 3 days even when accelerating the dry times using a food dehydrator or other type of speed-drying method. The color comps given on page 1 are not easily driven in, so you may employ forced drying methods without fear of ruining the devices.

Once the pressed color comp is dry, bind all your shots into a bundle using a rubber band and load them all 2/3 full with the flash powder of your choice, as seen in Figure 7. The special scoop shown here, which was crudely fabricated from a sheet of thin aluminum, allows the tubes to be charged without the use of a funnel to guide the powder.

Once loaded, the tubes can be plugged with either hot glue or a 1/2" paper end plug. When using hot glue, it is necessary to fist plug the tubes with a wad of paper to prevent the glue from seeping into the flash charge. If these shots were to be used as inserts in a canister shell, then hot glue would be the required plugging method in order to prevent gas leaks from setting off the reports when the shell breaks. Figure 8 shows the wads of paper inserted into the tubes. The excess flash is blown off the tubes where the hot glue will contact the tube walls so that it will not reduce the adhesion of the glue.

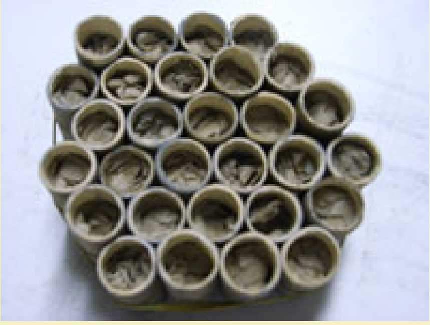
Figure 8: Paper wadding stuffed into tubes.

Figure 9 shows the hot glue being used to plug the ends. If you are making these shots to use as shell inserts, it is very important at this stage to insure that there are no pinholes or air gaps in the glue where hot gases could leak into the salute tube from outside.

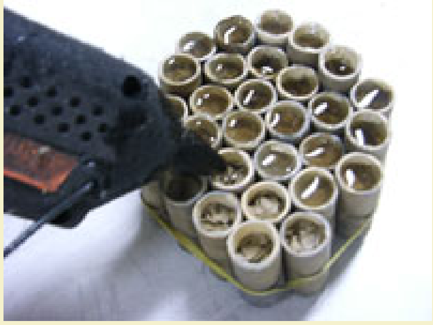
Figure 9: Sealing ends with hot glue.

Once the hot glue solidifies, the bundle is flipped over and the dried color composition is brushed with a slurry prime of BP. It is important that the color comp is fully dry before applying the slurry prime, as well milled BP can act as a pretty severe moisture barrier after it dries.

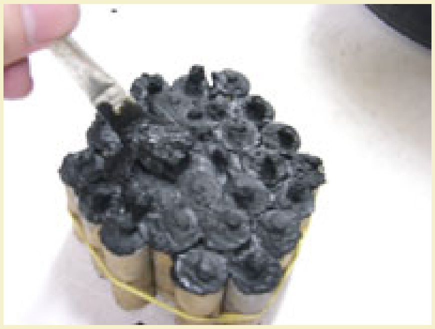
Figure 10: Brushing a prime slurry onto the dried color comp.

More...

Color to Report Cake

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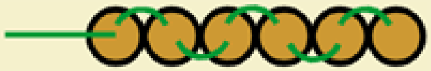

Figure 11: Basic fuse chain for single row.

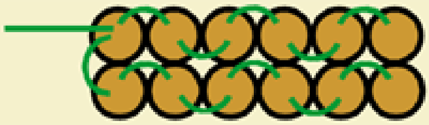

Figure 12: Firing pace increased with double row sequence.

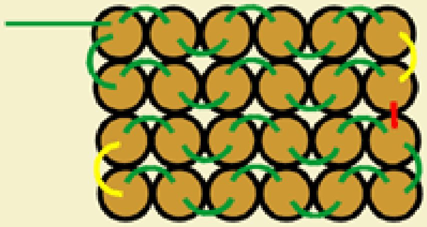

Figure 13: Complete cake consisting of two double row sequences linked together.

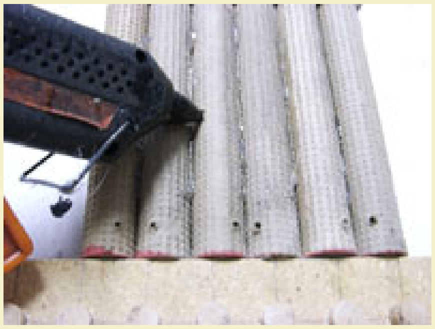

Figure 14: Glueing each row of tubes together before fusing.

Fusing Sequences:
One of the defining characteristics of a true cake is that all the shots are fused from the bottom. Cakes that are produced by loading a rack of small mortars with small shells where the leaders are hooked into a time fuse chain are, in my humble opinion, just miniature versions of a display chain.

Half the battle in making good cakes is getting good timing out of your fusing sequence. Visco is the fuse of choice, since it does not easily ignite from the side from stray sparks. However, visco will side ignite other pieces of visco if in direct contact with it while burning, so care must be taken to insure that separate visco links do not come in contact with each other. Figure 11 shows the basic fusing sequence for a single row of tubes. The visco links alternate sides so that rows can be placed up against each other without their fuses touching, as seen in Figure 12.

Note that the entry and exit points of any given visco link do not directly face each other. While it would seem easier to just link the tubes right where they butt up against each other, doing so would frequently result in a chain reaction where two or more shots fire together. This is because the lift gases can shoot around the sides of the fuses from one hole into the next. I have seen entire rows blow all at once because of this.

Because the holes must point away from each other, longer pieces of visco must be used to bridge the gap. Due to the slow burn rate for visco, the configuration shown in Figure 11 would burn with rather large delays between shots. Figure 12 shows how the pace can be quickened by linking in a second row with a slightly longer piece of visco so that it fires in parallel but out of sequence with the first row.

Figure 13 shows the fusing sequence used for the cake described in this article. It is basically two blocks constructed as shown in Figure 12, then linked together by the short fuse shown in red. While this violates the rule of avoiding fuse holes that face each, I would rather have a double fire and get a quick connection to the next firing block rather than have a long delay. The optional fuses shown in yellow are backup paths in case there is a break in the chain. If one visco link fails to ignite, the other row will loop around and eventually fire the stranded shots. I suspect that a similar feature in commercial cake chains is responsible for the renegade, never ending cake that sometimes ruins a show segment by firing single shots at a slow pace for what seems like an eternity.

Constructing the Mortar Block:
The tubes used here are 5/8" I.D. x 6" long cores that once were rolls of twine. A 1/2" plug of clay was rammed into the bottom of each one and a 1/8" hole drilled through both sides of the tube right above the plug. The tubes were then arranged in groups of six and held in position with a bead of hot glue, as

seen in Figure 14. The tube rows are much easier to work with when they are connected together like this prior to fusing. Make sure that the fuse holes are angled towards each other in the alternating pattern shown.

Next a batch of 1-1/4" long pieces of visco are cut such that each end is at a sharp angle, as seen in Figure 15. Not only does this angle make it easier to insert the visco through the holes, it increases its ability to take fire by exposing a larger surface area of the powder core and also providing a sharp edge that will easily ignite. Prepare 20 pieces that are 1-1/4" long and 4 pieces that are 1-5/8" long. The longer pieces will be the connectors at the ends of the rows.

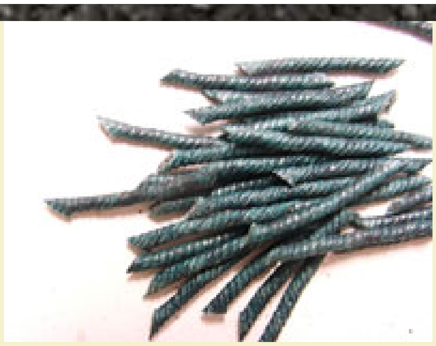
Figure 15: Cutting visco at a sharp angle to increase its ability to take fire.

First insert the shorter fuse links into the hole pairs as seen in Figure 16. You will then have four rows of six tubes that are fused together. Arrange the rows next to each other so that the visco links don't contact each other, as seen in Figure 17. Choose one end for the connector link between rows two and three, which will be the red link shown in Figure 13. Use an ice pick or drill press to make the extra holes necessary to install this link.

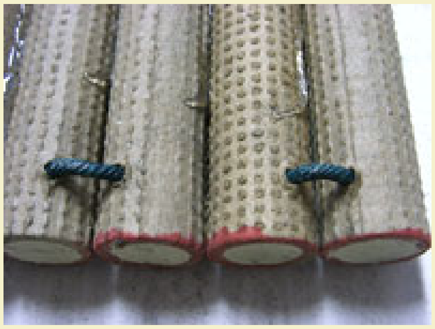
Figure 16: Closeup of visco fuse links.

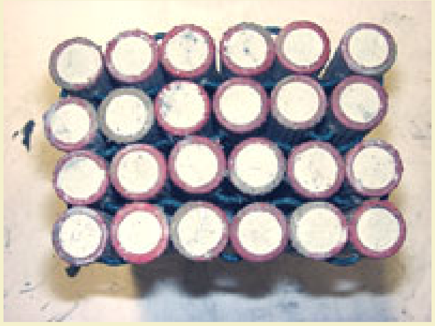
Figure 17: Bottom view after all tubes are fused together.

After installing the cross link, bind all the rows together with fiber tape so that you have a sturdy block. Now you can install the 1-1/2" links at the ends that will connect the rows to each other. You may need to make a few extra holes to do this. Don't worry about empty holes that don't get used.

Loading:
The cake is now ready to be loaded. I lift each shot with about 5 grams of home made 3Fg black powder. The amount of lift required will vary widely based on your tube length, tube diameter, grain size and strength of your lift powder. Thus you will need to single fire a few shots until you can dial it in.

Each tube is loaded with lift, followed by the shot (prime end down) and then a wad of paper to hold things in place. Figure 18 shows a 1/2" rod being used to force a scrap of 30 lb kraft into the hole and down to the top of the load.

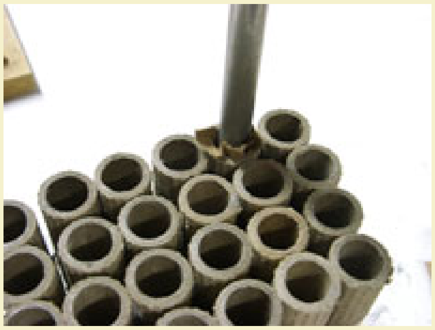
Figure 18: Pushing in retainer wadding after all shots are loaded.

Firing:
The cake shown in Figure 19 can be fire as is, or wrapped in paper or plastic for weather resistance. It is always a good practice to paper or foil over the tops of the tubes to prevent sparks from falling inside and igniting things out of order.

Be sure to block this cake in using something like bricks to keep the recoil from bouncing it over on its side while it is firing. Other methods of securing it include driving wooden stakes around it, tying it to a single stake, fastening it to a wide wooden base or bagging the cake and digging it into the ground.

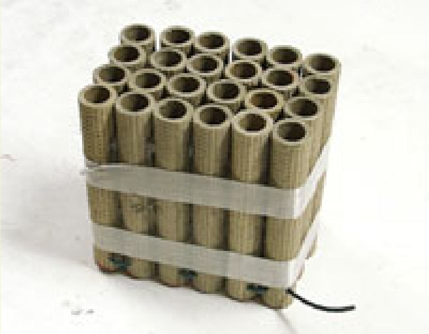

Figure 19: Finished cake held together with a few bands of fiber tape.

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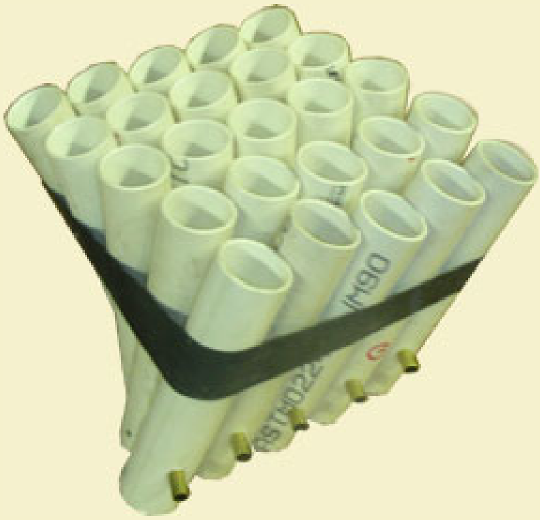
Volume 4, Issue 5

Build This...

Reloadable Fan Cake



October, 2004 Issue

Build This:
Reloadable Fan Cake

Technique:
Core-less Microstars

Technique:
Mixing with Screens

Tool Tip:
Making Screens

Class C Corner:
Wreckless, Home of the Brave

Summary:

Half the work in building cake items is in fabricating the cake shot tubes and tediously fusing them together. The cake shown here uses PVC and an innovative design for creating a 25 shot fanned comet cake that can be quickly reloaded and fired again and again!

Materials:

- (25) 5" long 3/4" I.D. 100 PSI PVC pipe
- (25) 7/8" O.D. x 3/4" long dowel rod segments
- (50) 3/4" long nails or tacks
- (5) 6" long 1/4" O.D. brass tubing
- (1) 5" x 10" piece of 3/4" thick wood
- (4) 4" long strip of 3/8" x 3/4" wood

Tools:

- Drill press
- Hack saw or cutoff saw
- Band saw or jig saw
- Deburring tool
- 1/4" drill bit
- 3/32" drill bits
- Hand reamer
- Clamps
- Hot glue gun
- Vice grips or vice
- Hammer

Unmeasured Materials:
Electrical tape, PVC cement, hot glue

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Reloadable Fan Cake...

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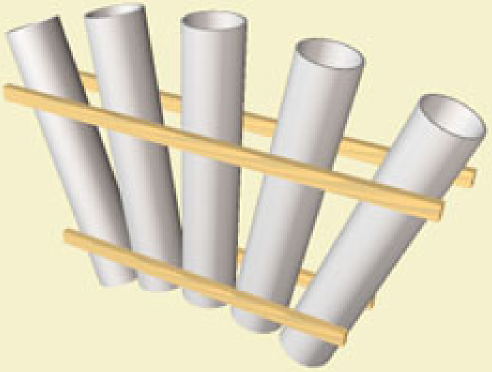

Figure 1: A conventional fanned mortar configuration.

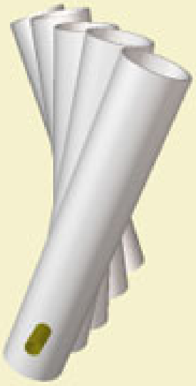

Figure 2: A more efficient fan configuration aligned on a common axis.

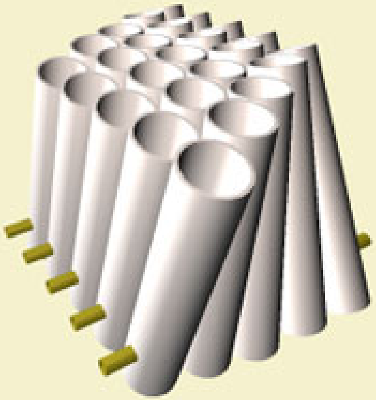

Figure 3: A block of five fanned rows.

Introduction

Firing groups of comets in a fanned formation is a great way to fill the sky both vertically and horizontally, giving a curtain of effects rather than just a central column. Achieving this effect requires two things: 1) having a group of mortars fixed at the proper firing angles and 2) making sure all the mortars fire at the same time.

Figure 1 shows how most commercial cakes construct their mortars to fire in a fanned configuration. Wooden braces or sometimes thin cardboard tubes are used to fix a row of mortars at the proper angles. Each successive row in the cake would share the braces from the previous row, such that you would have only one set of braces between each row of mortars. The shots are fused with black match that either feeds into a common piece of quickmatch running across the bottom of each row, or through just raw black match feeding in through holes directly across from each other in a straight line.

With so much manufacturing effort going into the fabrication of the mortars and their framed layout, one almost feels guilty throwing the spent carcass in the trash after use. For the hobbyist who has to do all the work constructing and arranging the mortar box himself, it is hard to justify the amount of work involved for 15 seconds of glory if the mortar box is only good for one use. It is for this reason that I have designed a fanned mortar box that is both reusable and easily reloadable, not to mention less complex, more compact and easier to construct.

While the method shown in Figure 1 works fine for commercial one-time use cake items, it presents a problem if the cake is intended to be reloaded. Once the rows of mortars are boxed together, you would have to pull them apart to get at the internal holes to re-fuse each row. Figure 2 shows the alternate configuration that makes re-fusing very simple. Instead of the mortars being aligned side by side, they are stacked onto a central piece of brass tubing that serves as a quickmatch pipe, a pivot point and a support rod. The tubing is perforated with holes that lead into each mortar, then fused by inserting a single piece of black match from end to end. The tubing is constricted at one end and ignited at the other end, resulting in instantaneous jets of fire from each passfire hole upon ignition.

The twisted arrangement shown in Figure 2 is a little unwieldy to use as a single shot fan, but when blocked together with many identical rows, they nest solidly to form a compact cake block as seen in Figure 3. The tubes are all glued to each other, so there is no need for a complex frame of cross supports.

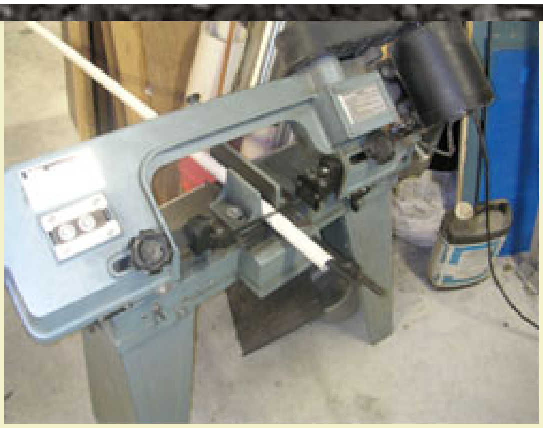
Figure 4: A vertical bandsaw makes cutting PVC mortars fast and easy.

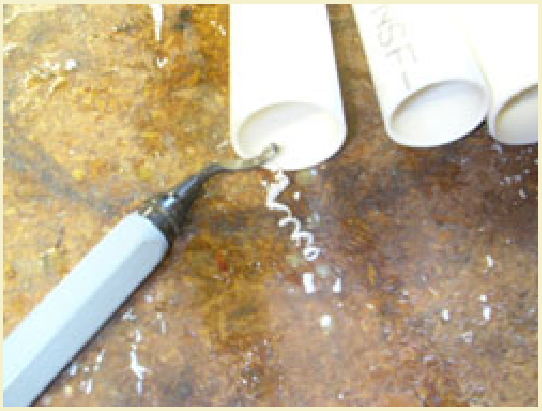
Figure 5: Using a deburring tool to trim the rough edges inside the tubes.

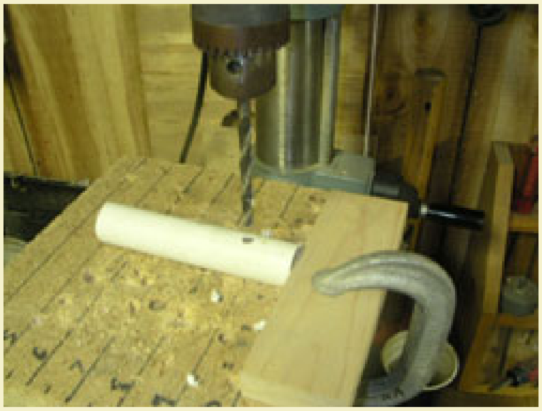
Figure 6: Drilling 1/4" fuse pipe holes 1-1/8" from bottom of pipe. Note use of stop block to eliminate the need to measure each hole location.

Rather than firing in a left-right orientation to the audience, this new method fires front to back. However, the effect looks identical to the viewer. The finished cake block looks a bit like a modern art sculpture, or perhaps a cake that was twisted up in one of Florida's recent hurricanes!

Constructing the Cake:
Like many things in pyro, building this project entails fabricating many small tubes. However, at least we won't be rolling the tubes from scratch this time. PVC makes an ideal mortar for shooting comets and other items that don't contain flash powder. Because PVC fragments into small pieces when blown apart, the rule of thumb is not to launch anything from PVC that will blow up the tube if it fails to lift.

The cake shown here is designed for 3/4" diameter loads, so a piece of 1" O.D. thin wall 100 PSI PVC works well. The inside diameter of this pipe is about 7/8", making it an ideal fit. I cut the tubes to 5" lengths, but you may up it to 6" if you want to conserve on lift powder. The longer the tube is, the more sensitive it will be to excesses in your lift measurements, which can result in comets getting blown blind if you are not careful.

This cake uses five rows of a five shot fan configuration, thus you will need to cut 25 tubes. While a pipe cutter can be used to do this, it is much faster to use a thin kerf Japanese handsaw or, even better, a vertical cutoff saw as seen in Figure 4. The one disadvantage to the sawing methods is the ragged edges left on the tubes, so some extra time will be spent sanding them and cleaning out the dust. Figure 5 shows a simple deburring tool that makes cleaning the inside edges of all the tubes quick and clean.

With all the tubes cut and cleaned up, the next task is to drill the pivot hole where the brass passfire tube will pass through. The diameter of this hole will naturally be the O.D. of whatever tubes you find to use as the passfire. I used 1/4" thin walled brass tubes from the "K&S Metal Center" displays found in some hardware or craft stores.

Figure 6 shows a drill press with a stop block clamped to the table surface, eliminating the need to measure out and mark the hole center point on each tube. The holes will need to be 1-1/8" from the end of the tube, and will run all the way through both sides of the pipe.

Once all the holes are drilled, the tubes are ready to be plugged. I used segments cut from a 7/8" O.D. dowel rod to form 3/4 thick bottom plugs. Unfortunately the dowel rods are typically undersized and have a considerable gap when placed in the tubes. This problem is overcome by wrapping each plug with about 4 to 5 turns of electrical tape, which enables them to fit snugly in place.

The mortar plugs are held in place by two small nails hammered in from opposing sides of the tube. The nails will not split the PVC or the wood plug, so there is no need to drill pilot holes. Be sure the nails are not placed directly under the passfire holes, since they would prevent the tubes from making good contact.

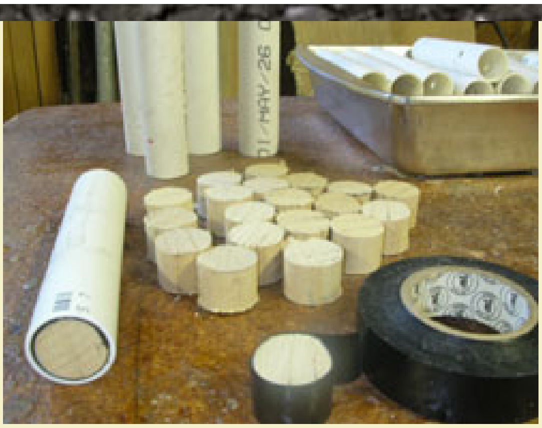
Figure 7: Plugging bottom of tubes with 3/4" long wood plugs cut from a 7/8" dowel rod. A snug fit is obtained by wrapping 4-5 turns of electrical tape around each plug.

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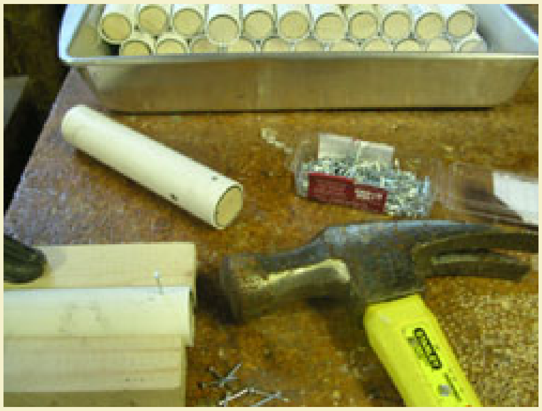
Figure 8: Using two small nails to hold each plug into the tubes.

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With the mortars finished, the next step is to fabricate the metal quickmatch tubes. I am using 1/4" O.D. brass tubes with less than a 1/32" wall thickness. Using tubes smaller than this makes it difficult to drill holes in the side, while going larger is not really necessary unless you plan to use some very thick black match inside. Because the black match will be completely protected from bending, I only use a single strand of thin cross matching black match to fuse the tubes. This allows one continuous piece of match to run directly through the time fuse and down the entire length of the brass tube.

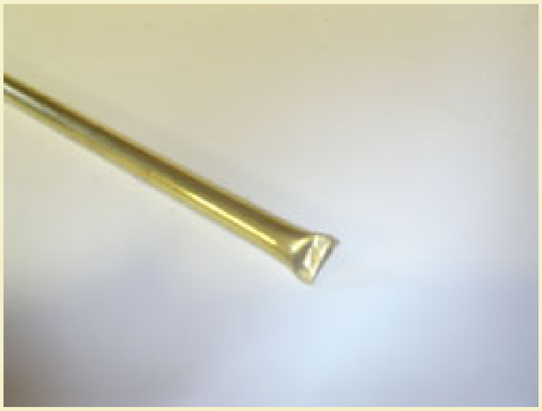

Figure 9: One end of each 6" long brass tube is pinched closed using a vise or pliers.

The K&S tubes are 12" long, which allows you to get two 6" tubes from each one. You will need one 6" long tube for each fan row in your cake box (5 in this case). One end of each tube is pinched closed as seen in Figure 9. This is best done by placing a solid rod inside the tube, leaving a 1/4" space at the end to be crimped, then crushing the end closed in a vice. The internal solid rod limits deformation near the end of the tube that would otherwise be caused if not supported internally.

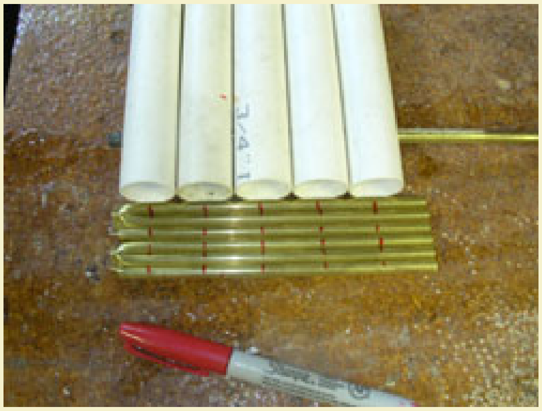

Figure 10: Aligning fuse tubes in front of mortars and marking passfire holes to be drilled.

Once all the tubes are crimped at one end, line them up in front of five mortar tubes as seen in Figure 10. Use a marker to mark where the center point of each mortar falls on the tubes. Be sure to position the crimped end to the left of the last tube, since it will be located on the outside once installed.

Next you will need to drill a 3/32" diameter hole at each of the marks you made. Because the drill bit will slide around and "skate" while trying to drill the side of a smooth tube like this, you will need to indent each mark with a center punch before drilling. Figure 11 shows the fluted match pipe being drilled out.

Now you are ready to install the brass tubes into each set of five mortars. Because each tube will likely be a tight fit, it helps to ream out the passfire holes very slightly with a hand reamer as shown in Figure 12. Be careful not to remove too much material though, because you do not want air gaps that would allow hot gases to escape around the brass tubes and potentially side ignite adjacent rows.

The brass tubes are inserted into the first mortar and pulled tightly so that the crimped end wedges into the hole, as seen in Figure 13. The passfire holes are aligned so that they point toward the bottom plug where the lift powder will be sitting. The comet or other insert will be sitting on top of the brass tube when the cake is loaded.

Once all five sets of mortars are assembled, you are ready to glue

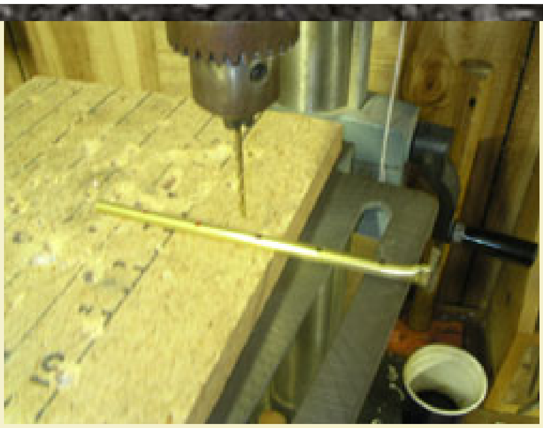
Figure 11: Drilling passfire holes with a 3/32" bit.

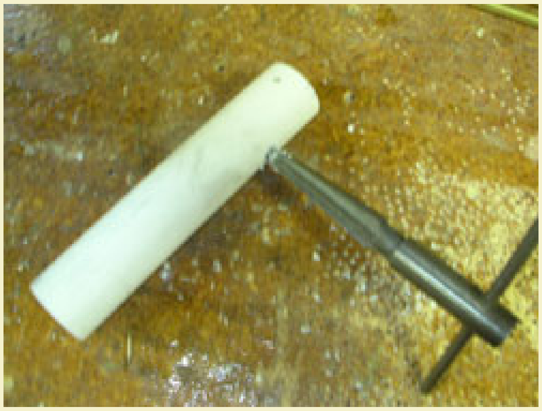
Figure 12: Slightly enlarging fuse pipe holes with a hand reamer prior to assembly.

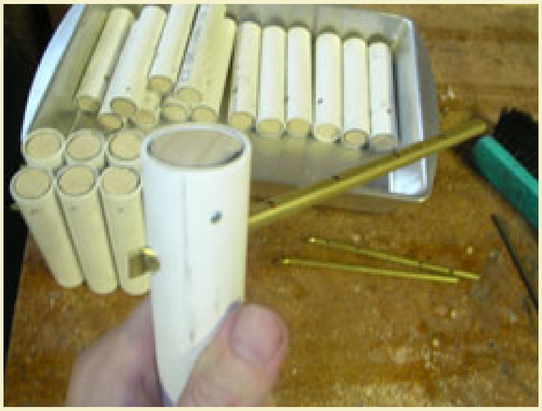
Figure 13: Sliding mortars on to the fuse pipes.

them into their firing positions. This requires a set of alignment jigs to be made from scraps of wood, as seen in Figure 14. Because there are five tubes in the fan, there are three angles that need to be set. The first angle is zero degrees for the center tube, which fires straight up. The second angle is 10 degrees for the tubes on either side of the center tube, measured from the vertical position. The last angle is 20 degrees from vertical for the two outside tubes.

This is about the minimum spread that you would want for a fan. For a wider spread, an angle set of 0, 15 and 30 works good. ShowSim can be used to experiment with the appearance of various fan angles using the effect front generator. The ShowSim simulator adds random drift so that you will get a better feel for what your cake is likely to look like in real life. It is good to be sure you are setting the angle you really want before proceeding beyond this point, since it is difficult to rip the tubes apart if you change your mind later.

The three angles are measured onto 3/4" thick scraps of wood that are 2" wide by 5" tall, then cut out on a band-saw. Two additional 3/8" thick spacers are required between each angle block in order to keep the angles aligned with the mortars. These spacer blocks must be 4" tall to keep them from getting in the way. All five pieces are sandwiched together and held with a clamp as seen in Figure 14. It is not necessary to glue the pieces together, since this is only a temporary fixture for the alignment process. It is necessary to make sure that each block sits flat against the table when in use of course, otherwise your angles will be off.

Figure 15 shows how two sets of alignment fixtures are used to hold the tubes in their proper position. After making sure that each tube lies flat against the angled surface of each block, a bead of hot glue is applied between each tube to hold them together. The hot glue must be allowed to solidify before removing the tubes from the fixture. Hot glue provides a strong bond between the PVC, but also allows some flexibility that is needed when gluing the twisted rows together to form the final cake block.

It is a good idea to trial fit your five fan rows together before applying any glue, as seen in Figure 15. This helps detect any alignment errors before it is too late. The hot glue can be cut off and re-assembled if any gross alignment problems are discovered.

Lastly, PVC cement is used between the tubes of adjacent rows in order to lock the cake into one solid assembly. Care must be taken to insure that the center tube always points straight up during this process, as it is easy for the rows to skew side to side and mess up the collective alignment.

At this point the hard part is done, and the good news is that you will get many uses out of your cake before you ever have to go through this again!

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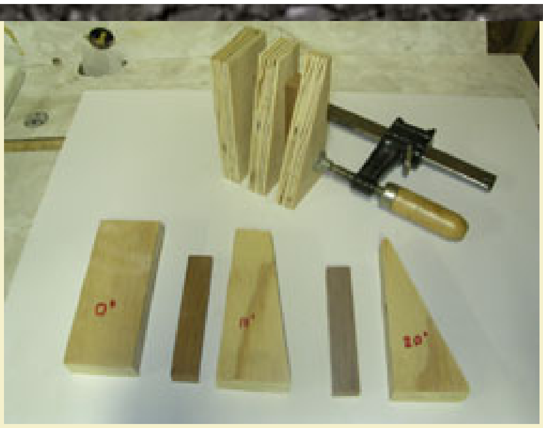

Figure 14: Building the angle fixture used to hold the mortars at the proper angles during gluing.

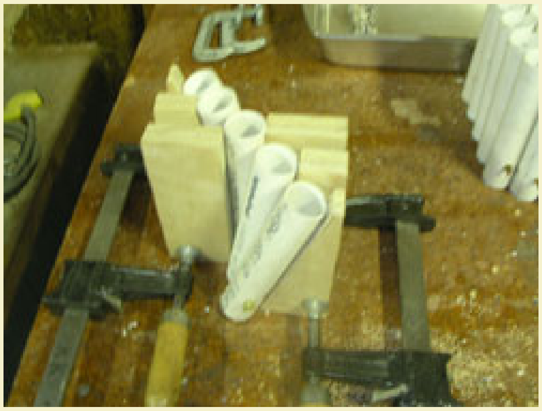

Figure 15: Two angle fixtues are used to align the tubes while hot glue is applied to fix them in place.

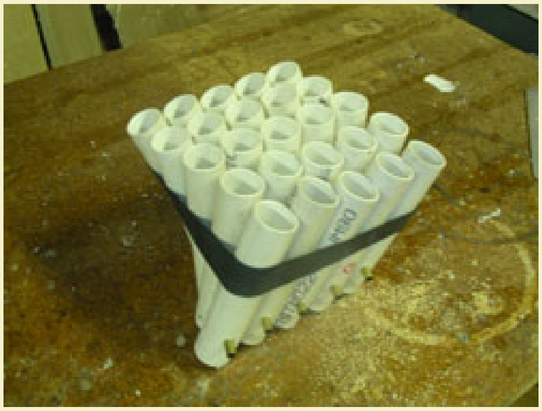

Figure 16: The five rows of angled tubes are finally banded together using PVC cement between the tubes to secure them into one solid block.

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Reloadable Fan Cake...

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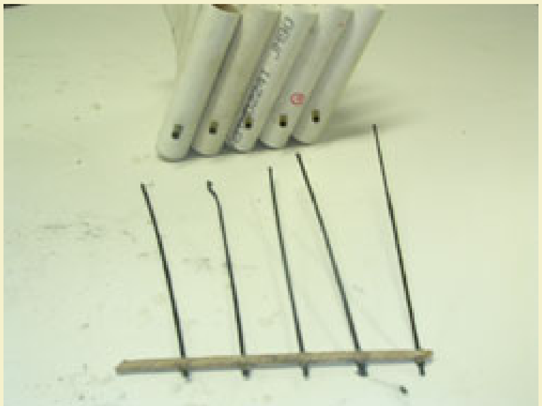
Figure 17: Crossmatching one continuous piece of time fuse.

Loading the Cake:
This cake is probably the easiest cake to fuse you will ever see. A single long piece of time fuse is punched and cross-matched at five locations with sticks of black match that fit all the way down the length of the brass tubes. I have used 1-1/4" spacing between the match holes for this cake, which will give about a 3 second delay between each of the five fanned shots. Leave at least two inches of time fuse extended before the first shot, which will be the ignition point for the cake.

Once the time fuse is cross-matched, the black match pieces are inserted into all five tubes at once and slid all the way in as seen in Figure 18. Strips of foil tape are then used to seal around the exposed black match to prevent cross-ignition. Be sure that there is some bare time fuse exposed between the tapped joints, otherwise hot gases from the cross-match ignition can shoot down under the tape and set off the next fuse simultaneously. Also be sure that the tape is sealed firmly around the time fuse for this same reason. The tape on the last ignition point should also cover the back end of the time fuse, since there is an exposed powder core there. If there were a Murphy's Law of fireworks, it would be "anything that can take fire, will." With this in mind, cover the ignition end of the time fuse with a piece of masking tape until it is time to fire the piece.

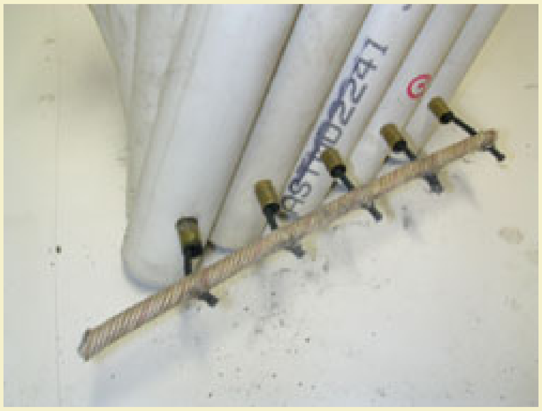
Figure 18: Inserting parallel blackmatch sticks into brass pipes.

The best types of comets to fire from a fan cake will have very long tails, thus visually showing the fan shape from the ground up. In this example I am using silver flitter comets made using the Dixon Flitter from the formula database. This is a potassium nitrate based flitter that is considerably easier to ignite than perchlorate varieties. However, it is not as intensely bright as the perchlorate flitter formulas such as the Bleser White Flitter.

Once you have pumped the flitter comets, you will want to prime them only on one end. This is because flitter formulas burn very fast, so you want them to burn only from one end rather than from all sides at once. This at least gives you a little extra air time. It is not necessary to paste in the non primed part of the comet because it will not take fire from the lift charge.

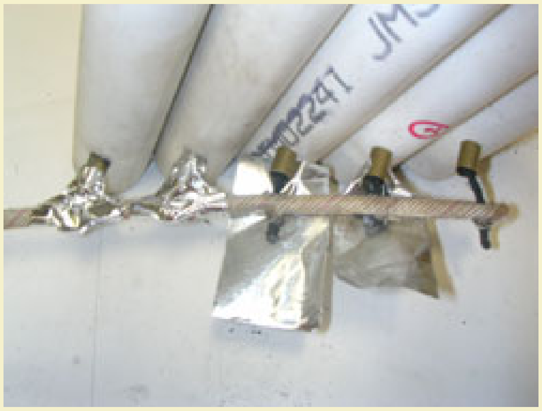
Figure 19: Protecting bare match joints with

The prime used here is ball milled meal with 5% dextrin mixed with 1 part aluminum flake per 40 parts meal. The flake can be bright aluminum, medium flitters, fine flitters-- it doesn't matter too much. The aluminum is just there to heat up the prime, and you could use other metals such as silicon or titanium as a substitute. The prime slurry shown in Figure 20 is made by adding 15 g of water w/20% alcohol to 25 g of prime. This is stirred to form a thick, muddy slurry foil tape.

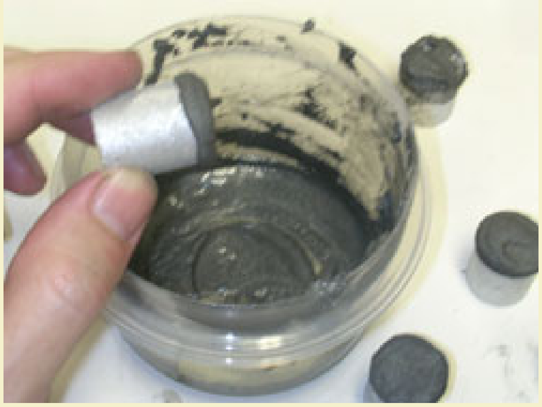

Figure 20: Slurry priming the ends of some 3/4" silver flitter comets.

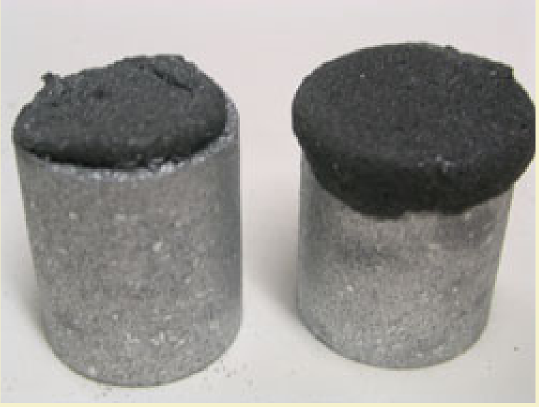

Figure 21: Inadaquate priming compared with effective priming.

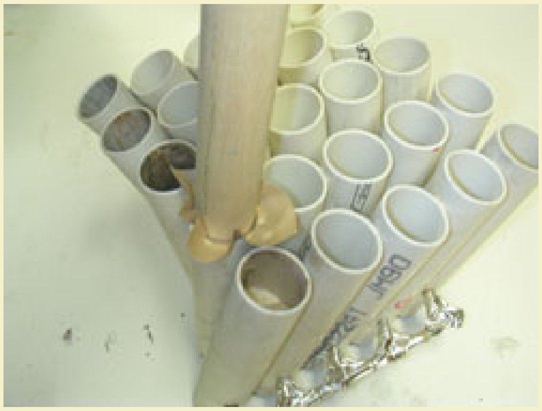

Figure 22: Pushing in paper sheets to form fire protection plugs.

that the comets will be dipped into.

When dipping the comets, it is important that the prime cover the corner edges of the comets, such as shown on the right-hand comet in Figure 21. The comet primed only on the end surface in Figure 21 will fail to ignite, since fire will not reach the corner edge of the comet where ignition temperature is the lowest. The end prime is also more likely to come dislodged from the comet surface during lift than is the fully dipped example. Care must also be taken not to let the prime get so thick on the sides that the comet won't fit into the cake tubes.

These comets will require about 1.5g of 2Fg in each tube for the lift charge. This could be more or less depending on the strength of your lift as well as how tight your comets fit into the tubes.

Once all the lift charges and comets have been loaded into each tube, a 2" square sheet of 30lb virgin kraft is pressed into each tube using a 7/8" dowel rod as seen in Figure 22. If recycled paper is used then it won't be strong enough for the tight fit and it will tear. This paper plug is a fire wall that prevents sparks from one row from falling down into unlit tubes and prematurely setting off adjacent rows ("anything that can take fire, will"). The plug does not need to be pushed all the way down into the tubes if you are going to fire the cake immediately. If the cake will be transported and potentially getting turned upside down, then you will need to push the plug all the way down to insure that the lift charge does not leak around the comet and pile up on the other side where it will do no good.

Use and Reuse:
When firing the cake, the position is orientated so that the brass tubes face the audience. It is a good idea to stake the cake down to the ground to prevent it from bouncing onto its side, especially if fired on a grassy lawn. Make sure any stakes used to not fall into the line of fire of some of the angled mortars.

After use, there will be a water-absorbing black slime inside the mortars that you will need to wash out with soap and water before firing again. Before getting the cake wet, try to extract the burnt black match strings from inside the brass tubes by dumping them out. Otherwise they can get wet and be difficult to extract.

There you have it, the worlds most compact and easy to use fan cake!

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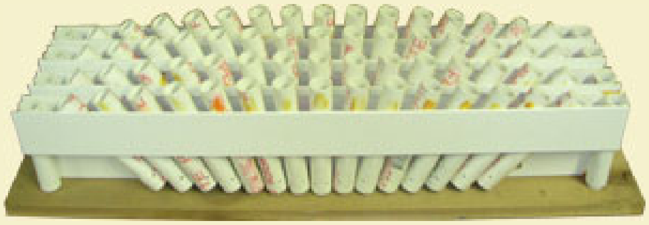
Volume 4, Issue 6

Build This...

60-Shot Z-Fan Cake



Summary:

Z-Fan cakes are a distinctive fan effect where many shots are fired one at a time in rapid succession, with the progression moving back and forth in a zig-zag fashion. These cakes have been appearing on both the commercial and consumer firework market in recent years, and a typical cake often exceeds 100 shots. Upon viewing one in action, one would think some kind of rapid burning visco had been invented to allow the fast yet precise timing of so many shots. However, as this article shows, these cakes are fused with nothing more than good old fashion black match!

December, 2004 Issue

Build This:
60-shot Z-Fan Cake

Technique:
Making KP Burst Charge

Gallery:
1st American Maltese Show

Tool Tip:
Making End Disks

Autopsy:
Peanut Shells

Materials:

- (60) 5" long 3/4" I.D. PVC tubes
- (8) 4" long x 3/4" I.D. PVC tubes
- (60) 1/2" long x 3/4" O.D. wood plugs
- (4) 4" wide x 22-1/2" long x 1/8" thick PVC sheets
- (2) 2" wide x 22-1/2" long x 1/8" thick PVC sheets
- (8) 4" long x 5/8" O.D. wood dowel rods
- (1) 25" long x 7" wide x 3/4" thick board
- (60) 3/4" long tacks

Tools:

- Belt sander or sand paper
- Hack saw or cutoff saw
- Small electric drill
- Deburring tool
- 1/8" drill bit
- 3/4" drill bit
- Bar clamps
- Hammer
- Hot glue gun

Unmeasured Materials:

PVC cement, Foil tape, 1/8" cross match, 2Fg lift, 5/8" stars or comets, 3/8" I.D. match pipe

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60 Shot Z-Fan Cake...

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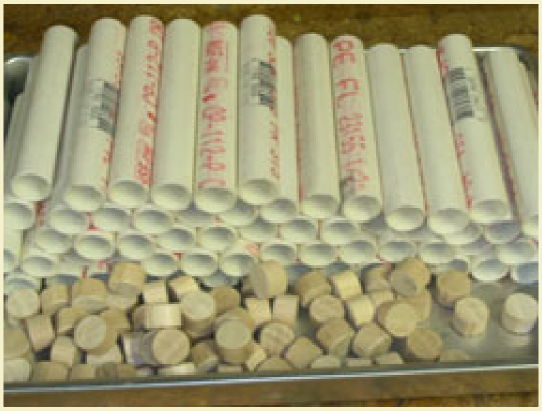

Figure 1: 60 tubes and end plugs ready for assembly.

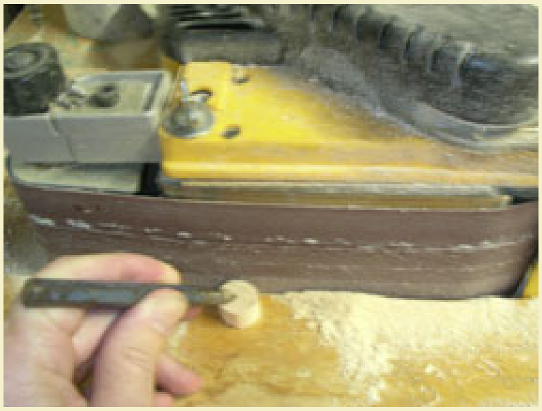

Figure 2: Using a belt sander to trim down wood plugs that are too large.

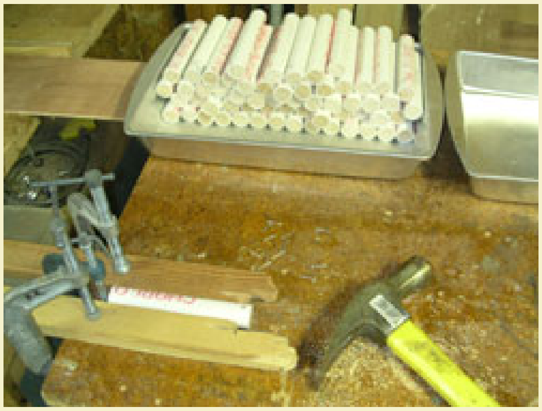

Figure 3: Bracing the tube while tacking the wood plugs in place.

Introduction

Last month we looked at a simple way to build fan cakes where all shots in a row fire at once. This month's project features a different kind of fan cake known as a Z-fan, which is a type of fan cake where all the shots in each row fire one at a time from left to right, then right to left, then left to right etc. This back and forth motion requires very rapid firing of adjacent shots in order to achieve the ideal wave-like motion.

The first time I saw a commercial Z-fan cake in action, I couldn't figure out what they were using to fuse the shots that would allow such a rapid progression. The shot rate is far faster than any type of visco fuse would allow, but slower than quickmatch would produce. As it turns out, the fusing is sort of a half-breed between quick match and raw match. Raw black match is in fact used to make the fuse connections between shots, but it is only partially piped. This loose confinement results in less pressure to drive the flame front forward as the fuse burns. There are a few other tricks used to control the timing, as discussed in the section on loading the cake.

The timing is so fast yet precise on the cake shown here that it was mistaken by some onlookers as a 10ms computer firing demo that was scheduled for the FPAG fall festival last month. The cake was actually fired as part of the multi-tube repeater competition, where it took 1st place.

Building the Cake

As you might guess, the majority of the work in building this cake is making all the tubes and building them into properly angled racks. For this reason I have opted once again to go with a re-usable PVC type design that can be washed out with water. However, the exact same procedure could be used to produce the same cake using paper tubes plugged with clay and connecting them together with sheets of corrugated cardboard. The paper cake carcass is actually faster to produce, but it can't be re-used as easily as the PVC type.

This cake features four rows that contain 15 shots each. It is best to use an odd number of shots in each row so that the center tube will point straight up and serve as a mid-point when building the cake. The number of rows is arbitrary and can be as many as you have the patience to build. Sixty tubes was enough for me, thank you!

The cake shown here is designed to fire 5/8" stars or inserts, thus a pipe having an I.D. of 3/4" was used. The PVC shown here has a 1/16" thick wall, which will actually play a role in how fast the shots are timed. The cake actually fired a little too fast for my liking and if I were to build this again I would use thicker pipe to slow the shot propagation down. Paper tubes are usually at least 1/8" thick anyway so they will not be a problem if you go that route. Note that going with thicker tubes will change the length of the rows and you will have to alter the dimensions given in this article. It is best to cut all your tubes first and then test align them in place on your divider material to see how long the rows need to be.

The tubes and plugs are cut and trimmed as shown in last month's article. If you haven't been able to justify buying a cut-off band saw yet, this project will certainly add incentive. I was able to build and assemble the entire cake rack in only 4 hours using the cut-off saw. Cutting all the tubes and dowels by hand would probably double this time. The sideways mounted belt sander shown in Figure 2 also helps speed up the trimming of burrs from the outside edges of the pipes and plugs. Depending on the thickness of your dowel, you may also need to use the sander to reduce the plug diameters very slightly so that they fit into the pipes. Wooden dowels tend to have inconsistent outer diameters, so if you test fit them into your pipe before leaving the hardware store you may find one that fits without the need for sanding.

Figure 1 shows all the 5" long pipes and 3/4" long plugs ready to be inserted. Since these small shot tubes are not subjected to much force, I just use a single 3/4" tack to hold them in place. Figure 3 shows a pair of wood strips used to brace the tube while tacking the plugs in place.

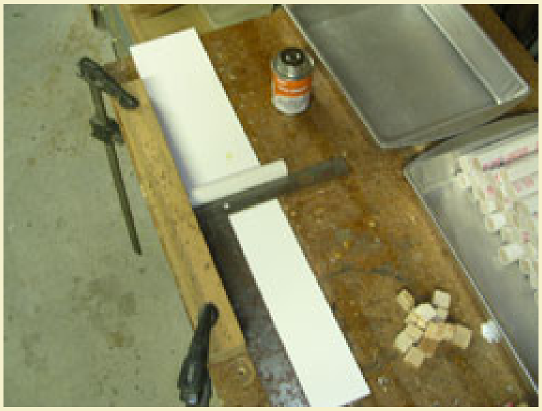
Figure 4: Using a wood alignment fence and an framing angle to mark the center tube.

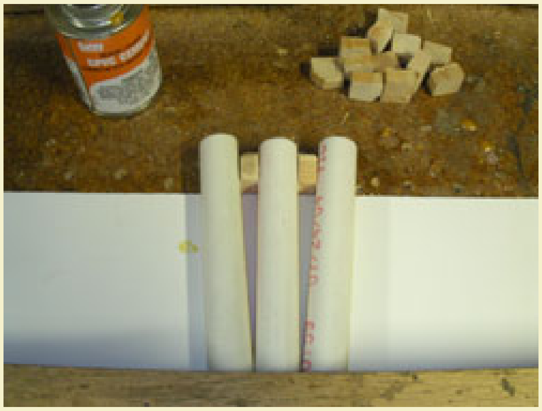
Figure 5: Using small 1/2" spacer blocks to set tube angles.

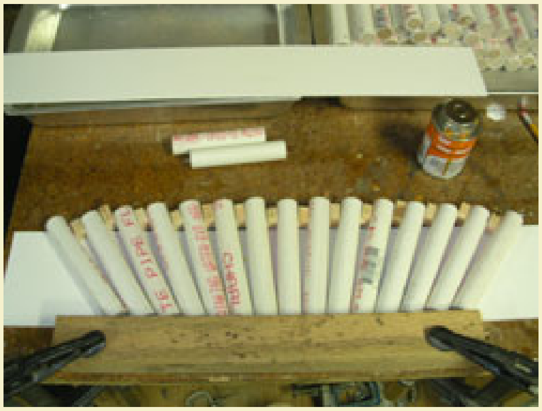
Figure 6: All 15 tubes glued into place on one of four plates.

Once all your shot tubes are complete, they are ready to be assembled onto the divider plates. The fuse holes for the tubes will not be drilled until the row assembly is complete, rather than worry about trying to correctly align pre-drilled tubes when gluing everything together.

If making the cake from PVC, you will need to acquire some 1/8" thick PVC sheets. These will be cut into 4 strips that are 4" wide and 4 strips that are 2" wide. This material is often used for making signs, so you could check with a local sign manufacturer as a potential source. If making a paper cake, then sheets of corrugated cardboard can be used in place of the PVC. If you are using different tubes than the ones shown here, then you will need to lay them out onto an oversized length of backing material to determine the correct row length, as shown in Figure 6. The angles are set by using small wooden blocks that are about 3/8" wide to control the spacing between the tops of each tube, rather than actually measuring the angles. The backing material should extend at least 1-1/2" beyond the edge of the last tube on both ends.

Once you have cut all your backing material to length, you are ready to glue all the tubes in place. If using cardboard, then hot glue can be used to quickly assemble the cake. The PVC cake is glued together with PVC cement, which sets fast enough to allow very rapid assembly of the tubes.

The assembly process needs to be done against an alignment block so that the tubes butt up against a common ground for alignment, as seen in Figure 4. Start by marking a center line with a framing angle,

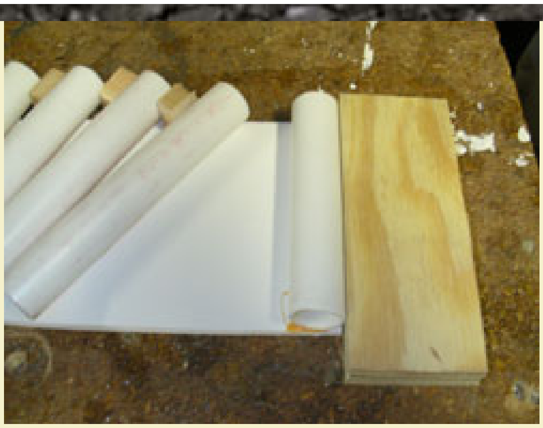

Figure 7: Attaching the guide tubes at each end.

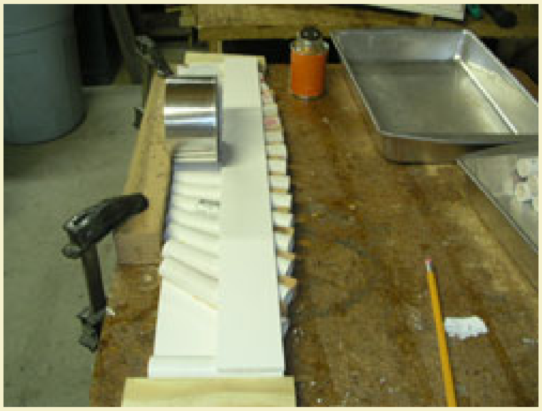

Figure 8: Gluing the front PVC strip accross all tubes to finish the plate.

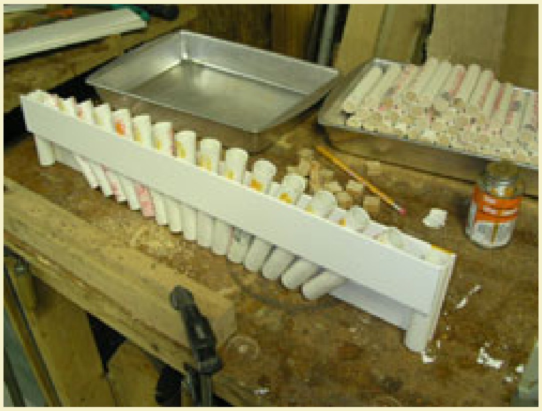

Figure 9: One of four fanned rows is completed.

which is where you will glue the first tube. Figure 5 shows how the spacer blocks are used to align and glue the next two tubes. This process is repeated, making sure the bottoms of all tubes contact each other, until all 15 tubes have been glued in place as seen in Figure 6.

Next you will need to glue a 4" long guide tube at each end of the fan plate, as seen in Figure 7. Use a block of wood held up against the end of the backing sheet to make sure each tube is aligned at the same distance from each end, and is also parallel to the edge of the backing plate. These tubes have no end plugs and do not fire anything, they will actually slide over wooden guide posts to hold all the mini-racks in position.

If you haven't passed out from PVC fumes yet, it is time to glue the 2" top plate across the tops of all the tubes. Regardless of weather you are using PVC or hot glue, you will have to apply the glue to all the contact points very rapidly so that you can set the top plate before any glue dries. The roll of foil tape shown in Figure 8 is just there as a spacer gauge, since foil tape will be laid across all the exposed tubes during the loading process.

Figure 9 shows one completed fan row ready for drilling. You still have three more to make, so get to work!

More...

60 Shot Z-Fan Cake...

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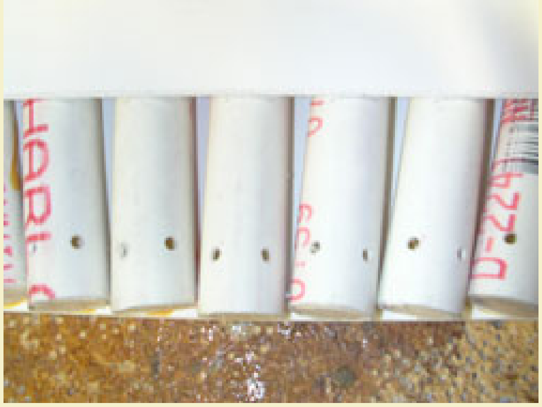

Figure 10: Drilled out 1/8" passfire holes.

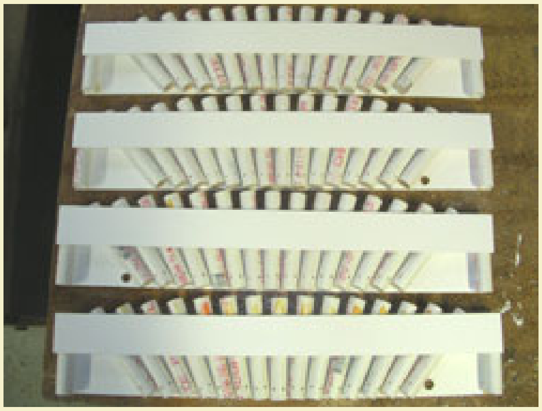

Figure 11: All four fanned rows completed.

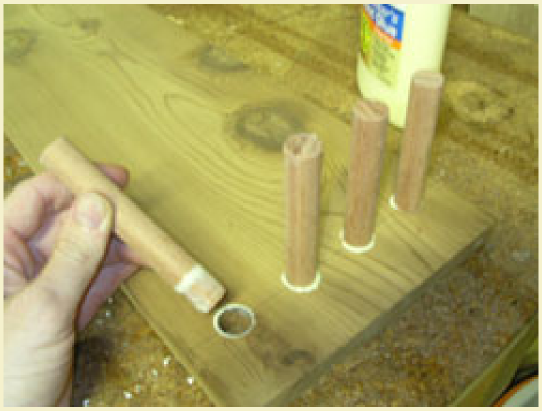

Figure 12: Gluing wood pins onto the holding fixture.

The next step in completing each fan row is to drill out all the passfire holes in each shot tube. A small hand drill such as a variable speed Dremel tool makes this job much easier. Make sure the black match you intend to use will fit into the holes you are drilling. I use a 1/8" hole, which works well when fusing with the thin type of cross match described here. It is important that the holes not be drilled so that they are too close together, otherwise the timing will be faster than desired. A 45 degree angle is just about right, as seen in Figure 10. The outer holes on the two outside tubes should be drilled directly into the side of the tube instead of at a 45 degree angle, otherwise the piped match connecting the rows to each other will be subjected to excessive bending.

Care must be taken not to drill your fuse holes into the wood plugs, which is an easy mistake to make when drilling the more angled tubes at the ends. The closer you get to each end of the rack, the more diagonal the adjacent fuse holes will be to each other.

Lastly you will need to drill 3/4" diameter holes at each end of the fan rack so that the piped match can be passed through the backing material. Figure 11 shows the minimum number of holes required for the Z-fan configuration, but it is a good idea to drill the passfire holes on both sides just in case you need it. Note that the back row does not need any holes, only the first three rows.

Once all your mini fan-racks are completed, you will need to make a holding fixture to keep them all in place. The simple fixture shown in Figure 12 and 13 is designed to allow easy assembly and disassembly of the racks when reloading the cake. The tubes on the end of each fan rack simply slips over the wooden pins, holding it upright and insuring that it does not tip over. The four pins on each side are spaced 1-5/8" from each other, measured from the center point of each pin. The spacing for each pair should be measured by placing the fan rack directly on the board and marking the center point of the left and right guide tubes.

Figure 14 shows the completed cake with all four rows loaded onto the holding fixture. At this point the hard part is done and the cake is ready for loading!

Well, I've said everything I can possibly think of to fill this column with text, yet there are still two images hanging down on the left margin. I don't want to get into the next logical section because the associated pictures are all on the next page, yet I can't stand it when the copy falls short of the image column. It just makes it look like I forgot to finish the article or got lazy and went to bed early or something. So

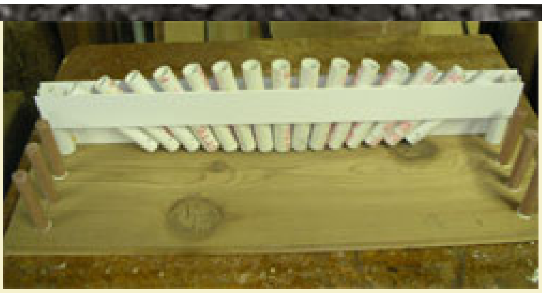

Figure 13: Shot rows slide onto support pins.

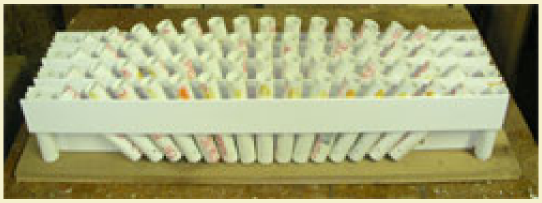

Figure 14: Completed cake ready for loading.

please bare with me while I ramble on about nothing at all in order to fill this space for the higher purpose of visual design asthetics. OK, close enough. Thanks for your patience and now back to our regularly scheduled Build This column...

More...

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60 Shot Z-Fan Cake...

Page 4

Loading the Cake:
Once you have the cake mortar racks completed, it only takes less than an hour to load it. Begin by removing all the racks from the support base and linking each set of holes with a length of thin black match. The quality of the match used here is very important, because it will get bent in several places, which will cause the outer coating to chip off. If your match is not internally saturated with black powder, then you will be left with dead spots in the fuse chain that risk causing the cake to stop short of firing all the shots. Good match should not reveal any white threads when bent or cut in half, otherwise you are going to have ignition problems. The match used for this project was made as described here.

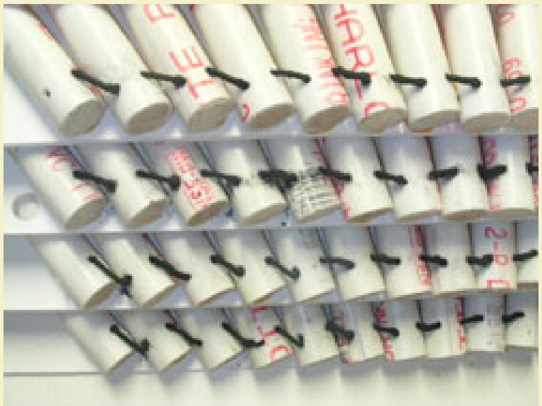

Figure 15: Fusing shots together with segments thin blackmatch.

Using segments of black match that are about 1-1/4" long, connect each pair of adjacent shot holes in all four racks, as shown in Figure 15. You are going to have to bend the match at right angles in a few places to do this. Sometimes the match sticks will get too mangled to insert and you have to toss it, so be sure to cut a dozen more pieces than you actually need.

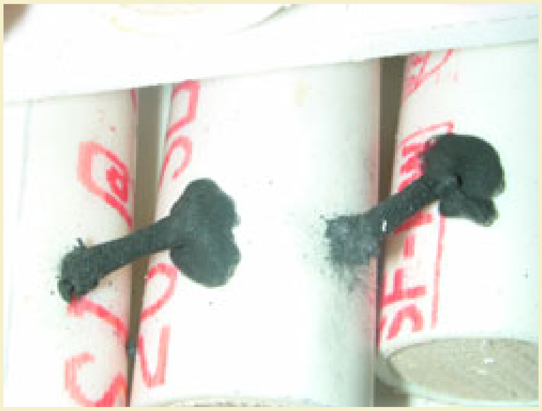

Figure 16: Painting prime slurry over holes that recieve fire.

The next step is the key to prevent a rapid fire chain reaction. Using a black powder prime slurry and a small cue-tip or paint brush, paint prime over each fuse hole that will be on the receiving end of the fuse fire. In Figure 16, the shots will be igniting from left to right, so the right side of each passfire link gets the prime protection. This step prevents the gas and fire from blowing out one shot hole straight into the next shot hole, thus bypassing the fuse and eliminating the short delay element. Thus it is important to make sure the prime fully seals off around the fuse so that no gaps are left open. The prime can also be used to patch up any areas of excessive powder loss on the black match itself if you are worried about dead spots. Due to the confinement around the fuse connections, the entire black match connection tends to take fire all at once, so you can actually get away with some pretty beat up fusing.

Applying the prime to both input and output holes may be one way to slow the cake progression down when using the thin wall tubes shown here, although I have not tried it at the time of this writing. It seemed to me that just the one prime block would add enough delay, but in reality it burns through in just a fraction of a second.

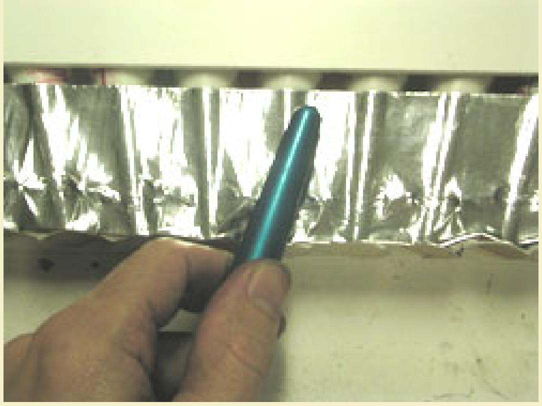

Figure 17: Making sure all air gaps under

Once all the priming is done, set the racks aside to dry for a day (or half a day in a drying box). When the prime is dry and solid, the next step is to cover all the match connections with one continuous strip of foil tape. The tape not only serves to protect the match from side igniting out of order, it also adds some confinement to increase the tape are sealed off to prevent gas from skipping ahead.

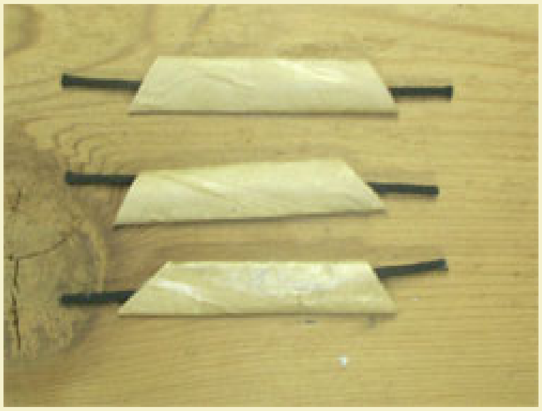

Figure 18: Piped match segments for connecting the rows together.

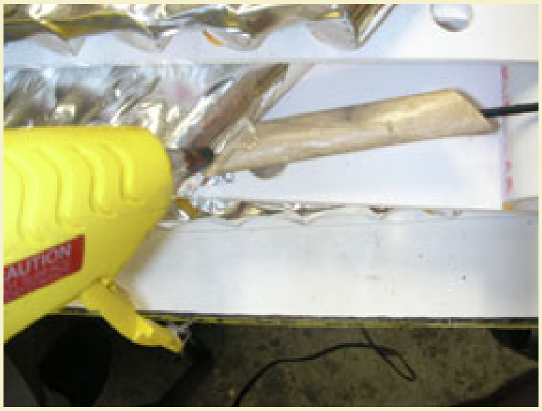

Figure 19: Using hot glue to connect piped match segments.

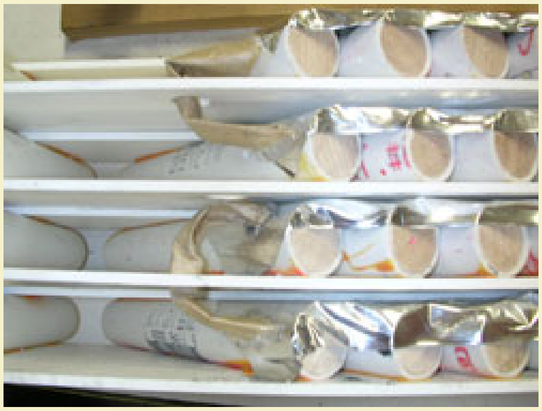

Figure 20: Piped match connecting the rows together.

fire transfer rate. Even though the black match links are not completely enclosed in a pipe the way quickmatch is, there is still enough enclosure around it to semi-trap the gas and fire. This results in a burn rate that is slower than quick match yet considerably faster than if the 1/2" fuses just burned end to end in open air.

When applying the foil, be sure to iron out any wrinkles or gaps under the tape where it contacts the shot tubes, as seen in Figure 17. There will still be enough gas pressure when the fire is transferring between shots to shoot under any gaps in the tape, thus short circuiting the desired shot and causing two or more shots to fire at once. This is a common problem that can be seen even in the commercial Z-fan cakes. The commercial cakes use gummed paper instead of foil tape for this purpose, and I think air gaps are harder to prevent with that method. I also prefer the foil tape for it's ease of use, superior fire resistance and ability to stick to plastic.

At this point the four racks are ready to be chained together in the correct firing sequence. This will require that you make three piped match segments as seen in Figure 18. The pipes shown here are 3/8" I.D. and measure 3-1/2" long. The ends of each pipe are clipped at about 45 degrees to account for the angled tubes they will be connecting to. A single strand of high quality match measuring 4-1/4" long is passed through each tube.

Begin by fusing the last row first, which is laid flat on a table foil side up. You will only be making one connection on this row, either on the left or right side depending on the firing sequence you want. It is important that you keep track of the designated firing direction as dictated by the holes you protected with prime. If you get it backwards and start from the wrong end, then the cake will rapid fire and ruin the effect. Peek under the tape and make sure that the tube you are fusing into does not have the prime slurry on it. If you primed both input and output holes with the slurry then you don't have to worry about this issue and you can pick an arbitrary side to fuse into.

The fuse pipes are connected to the side of the shot tube with hot glue, as seen in Figure 19. Make sure the glue fully seals the air gap as much as you can, otherwise fire could sneak in there and set things off out of order.

The connection you just made was an "input" connection, so next you will be connecting the other end to the output of the 3rd row. Place the 3rd row on top of the 4th row and feed the piped match through the hole you drilled for this purpose. If you foiled over any of the fuse holes you should open them all up with an awl or pencil tip at this point. Be careful not to rough up the black match when pushing it through the hole, since the tip can become too damaged to fit into the hole and that would force you to redo the previous connection in order to replace the match.

Continue the same fusing process, starting on the opposite end of the 3rd row and fusing up to the 2nd row. The fusing will snake back and forth as seen in Figure 20, stacking the rows on top of each other as you go. Once all four rows are fused together, carefully pick up the stack and invert it onto the support base. You will have to set one row at a time and pull the others out like an accordion until all the rows are seated over the pins, then push them all down to the base at once.

Finishing the loading process from this point on is a piece of cake, no pun intended (OK, the pun was obviously intended but tradition requires me to deny it). Each tube gets 1/4 teaspoon of 2Fg lift, followed by a star, followed by a compression plug. It is actually faster to add the lift to all tubes first, then the stars to all tubes etc rather than completing each tube one at a time. However, care must be taken to keep track of the last tube loaded, otherwise it is easy to accidentally add a lift charge or star to the same tube twice! I like to keep one finger pointed at the next tube to be loaded while my other hand does the actual loading.

The paper plug being pushed into each tube in Figure 23 serves to protect from accidental ignition from above, and also keeps the lift from migrating above the star during transportation if the cake was ever accidentally tipped on it's side or upside down. These are made from 1-1/2" sheets of 30 lb virgin kraft and pushed in with a 5/8" dowel rod.

As one final precaution it is a good idea to foil over the tops of each row with strips of aluminum foil, as seen in Figure 24. This is done to prevent sparks from falling between the tubes during firing, which has the risk of igniting the exposed segments of black match and start the cake firing out of order. Keep in mind Murphy's rule of cake malfunction: "anything that can take fire, will." Skimping on precautions such as this can result in a lot of wasted effort in the end, so don't give in to temptation!

The star used in this cake was a 5/16" flitter core with tiger tail rolled up to a final 5/8" O.D. The effect is a thick gold streamer that releases a burst of silver at the top, making an attractive snowfall effect that follows behind the streamer progression. The most visually pleasing Z-fan effects are those where all shots are the same and some event occurs at the zenith of each shot, such as a salute, crossette, color change etc. This creates the appearance of a secondary effect that lags behind the motion of the swaying comets, as if chasing them from behind.

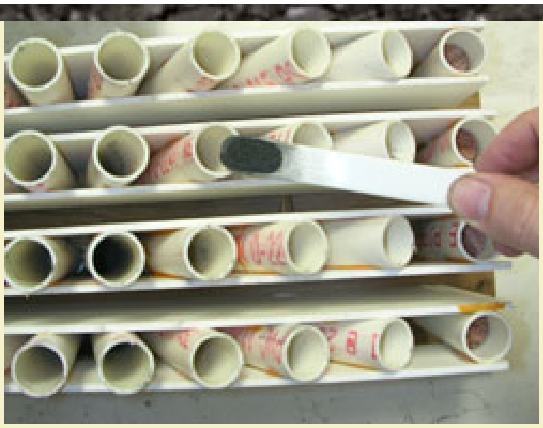
Figure 21: 1/4" teaspoon of 2Fg into each tube.

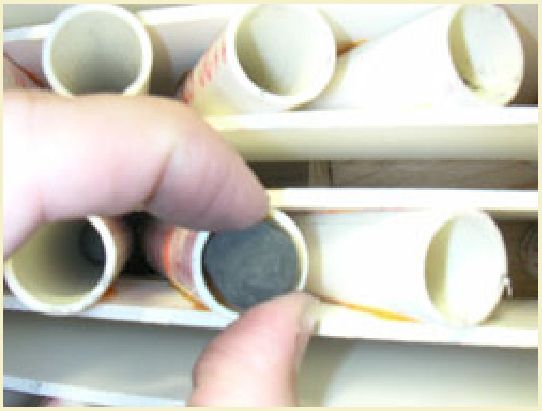
Figure 22: Inserting a 5/8" round star.

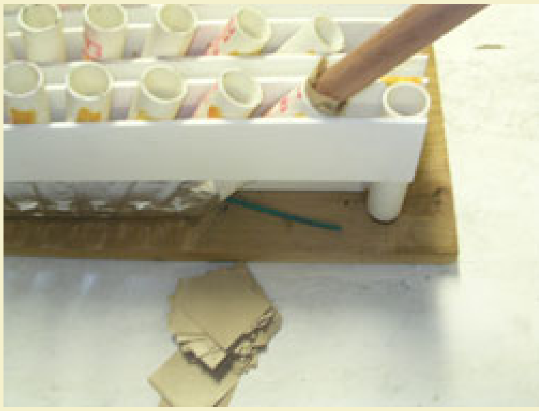
Figure 23: Pushing in 1-1/2" square paper sheets to plug each tube after loading.

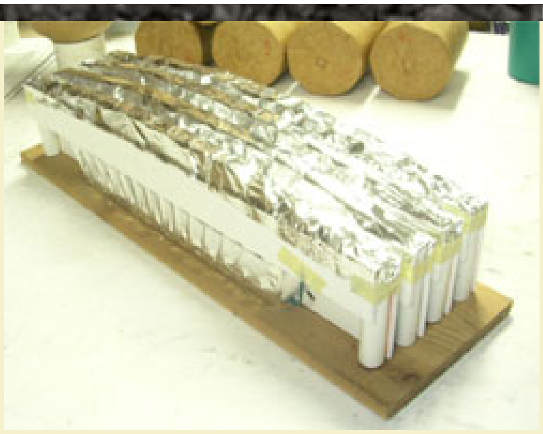

Figure 24: Finished cake ready for firing.

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Design Notes...

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Mass Launching Z-bombs

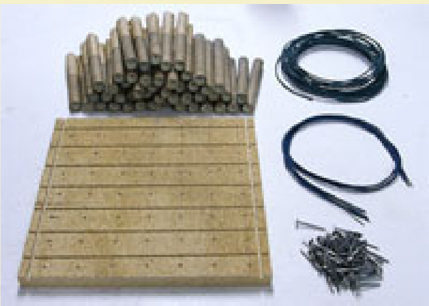

Figure 1: Perforated and grooved launch board.

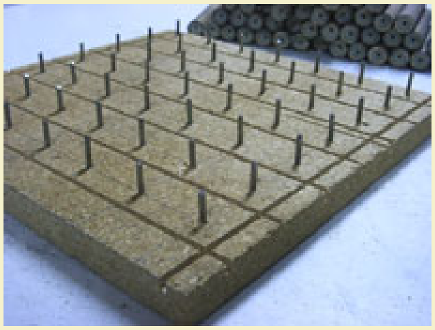

Figure 2: 1-1/2" roofing nails with points cut off.

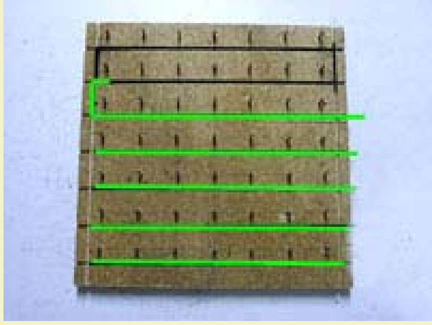

Figure 3: Main body visco path (green) and black match finale path (black).

Introduction:
This multi-shot Z-bomb launching device is a bit exotic and certainly a lot of work to make, but readers may find the techniques used for timing the shots applicable to other cake type items. Indeed, the most difficult part about making bottom fused cake items is getting the timing right.

Efforts that utilize unprotected black match as the fusing mechanism will almost always have accidental side ignition problems, caused when stray sparks propagate between the tubes and prematurely ignite other tubes out of sequence. Even the use of cardboard barriers between tubes does not prevent the problem.

The use of visco, the only ignition material protected from side ignition that is readily available to hobbyists, suffers from a slow burn rate. The Chinese have solved this problem through the creation of a faster burning visco type fuse, but this requires complex machinery to manufacture and is beyond the realm of what hobbyists can make themselves. Until this type of fuse is readily available on the pyro-hobby market, it is not an option for most of us.

In developing this multi-shot method, I tried several alternatives to visco. All of them involved a wooden base with 1/4" deep slots cut in rows as shown in Figure 1. This is easily done with a standard 1/8" wide blade in a radial arm saw set 1/2" above the table. Two side channels are used to intersect the parallel channels at both ends, which are used to route fire from one row to the next.

It is worth noting what didn't work before describing the final working method, in case any readers want to pursue these other methods further than I did.

Method #1:
The channels were filled with hot glue, into which a stick of black match was immediately pressed, then covered with hot glue again on top. This method resulted in inconsistent burn rates, skipping and quick-match like eruptions that fired down the entire row at once. Causes were likely to be gaps at the corners of the square channels that allowed gasses to shoot forward, as well as air pockets where the glue did not fully settle around the black match.

Method #2:
The channels were filled with a meal slurry level with the top of the board, then allowed to dry. Both hot glue and foil tape were tested for protecting the top of the powder channels, and both failed in the same way as method #1. Again, air gaps at the bottom corners of the square channels were suspected as the source of the problem.

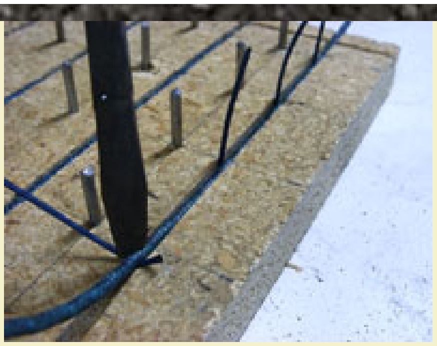

Figure 4: Locking in the 1/16" mini visco with 1/8" visco.

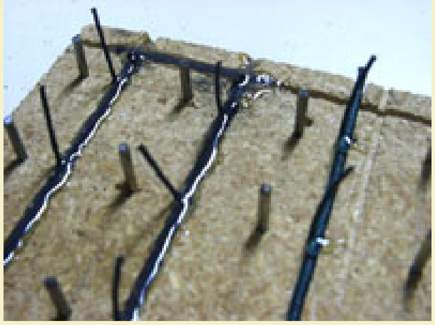

Figure 5: Hot glue applied over black match paths to protect from accidental ignition.

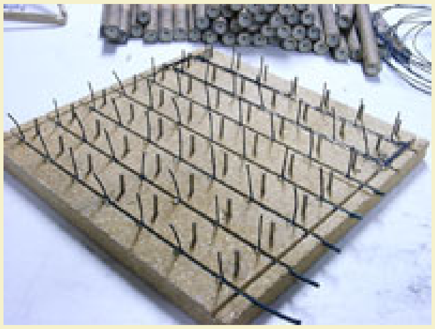

Figure 6: Launch board is fused up and ready for Z-bomb installation.

Method #3:
A special molding blade that cuts round bottom channels was used to eliminate the corners where air gaps form. Meal slurry was again spackled into all the channels and allowed to dry. Foil tape seemed to work the best at sealing over the tops of the filled channels. The skipping was not as bad as method #1 and #2, but still bad enough to prevent this method from producing reliable results.

While making black powder circuit boards seemed like a neat idea, it proved unworkable. The final solution was to use plain old visco laid into the channels, then ignite several rows at once such that each one was out of phase. In the 7x7 grid shown here, the first five rows burn in parallel but with staggered ignition times. The result is a rapid fire succession of Z-bombs leading up to a finale chain of two full rows fired at once.

Preparing the Base Board:
A 11" square piece of particle board was prepared with seven 1/8" wide channels cut 1/4" deep. This can be done with a table saw, radial arm, router or even a skill saw. The spacing between the channels was 1-1/2", with a margin of 1" at the top and bottom. Two more channels are cut 3/4" from each end to connect all the rows.

A 1/8" dia. hole must now be drilled in a 1-1/2" grid for the launch nails to be inserted into. The tips of these nails need to be cut off so that the Z-bombs do not wobble when loaded. Figure 2 shows the finished base loaded with nails.

Fusing the Channels:
Two types of visco fuse are required for this operation. The first type is the green variety of 1/8" diameter visco fuse. It is said that the green variety burns out the side more than the red variety does, although I have not verified this. Visco with plenty of side spit versus end spit is desired for this method.

The second type of visco is a very small 1/16" diameter type that is less common but still available if you search hard enough. I got mine at an FPAG 4F vending tent, so you might look for it at PGI as well.

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Mass Launching Z-bombs

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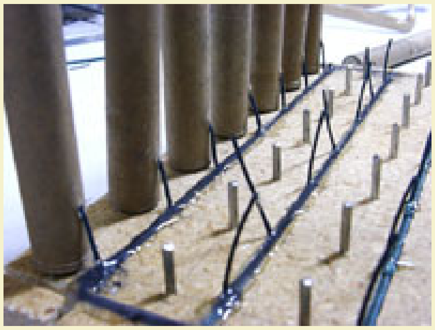

Figure 7: Inserting mini-visco into Z-bomb holes.

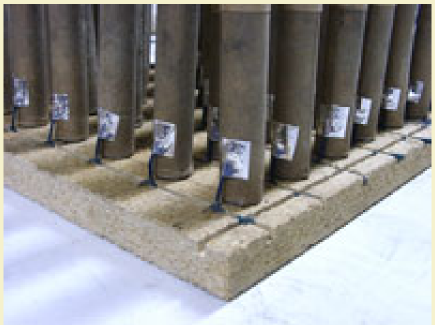

Figure 8: Securing fuse with a patch of foil tape.

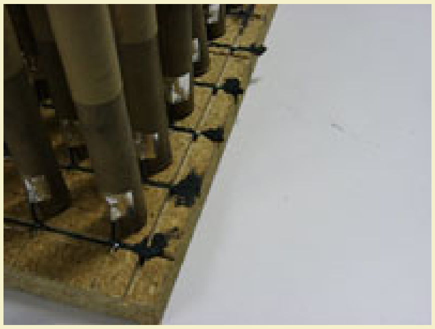

Figure 9: Slurry priming ends of visco chains.

First you will need to cut all your long 1/8" visco pieces that run down the channels. Figure 3 shows the pattern I used for this project. Note that all five pieces will be burning at the same time, so they are cut at slightly different lengths to stagger the ignition times. The longest piece loops around to the finale chain, where sticks of black match have been pushed into the channel.

Figure 4 shows how the thin visco is laid under the larger visco as it is pushed into the channel with a screwdriver. This firmly locks the fuse in place so that it can not be pulled out. It may be necessary to slightly widen the channel at the fuse points by drilling with a 3/16" bit. The lengths of the small visco will need to be determined by installing a Z-bomb and cutting the fuse such that it reaches the powder core while also allowing the Z-bomb to rest on the base. The bottom part of the thin visco should loop under the thick visco, but not stick up out of the channel. Once the proper length has been determined, go ahead and cut all 49 pieces. This is a perfect application for the anvil cutter length gauge.

Once all the thin visco ignition points have been pressed in place, a dab of hot glue is placed at the base of each one to protect the exposed black powder at the end of the thin fuse where it hooks around. Hot glue is also applied over all the exposed black match in the finale chain, as shown in Figure 5. It is important to seal down between the grooves at the ends of the channels and anywhere where a spark could sneak in and ignite the fuse chain out of sequence. Figure 6 shows the entire board fused and ready for loading.

Loading the Z-bombs:
Start installing the Z-bombs from the back row first. The fuse is first inserted into either one of the two Z-bomb vents, then the device is seated on the pin. Figure 7 shows a row of installed Z-bombs. Once a full row has been installed, small pieces of foil tape are placed over the fuse entry point to secure it from dropping out once the bottom of the fuse burns away prior to ignition. While Figure 8 shows only a small square of tape, subsequent testing proves that a full strip of foil tape that protects the entire length of the fuse is required to prevent accidental side ignition during launch.

Lastly you will need to prime the ends of all the visco chains to insure ignition. I like to cut the ends at a 45 degree angle to expose more powder core prior to applying the prime. Once the prime dries, a stick of black match is run across all the ignition points as seen in Figure 10. A final piece of visco is added to the end of the chain and a piece of foil tape is applied over the black match to protect it and create instantaneous ignition of all visco chains.

Figure 11 shows the completed 49 shot Z-bomb cake. Note the alternating use of salute and color headings. This chain fusing method can work equally well on multi-tube repeater designs, and adjusting the nail size will result in similar launch pad for stinger missiles.

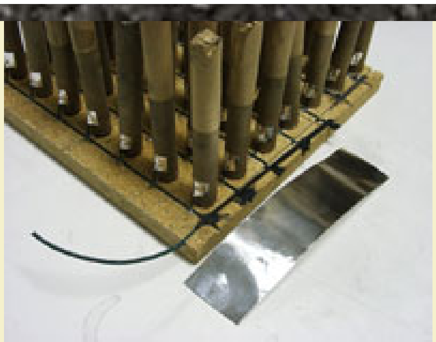

Figure 10: Stick of black match connecting all nodes together.

IMPORTANT NOTE:

Foiling the headers of each Z-bomb with foil tape is critical to insuring that the Z-bomb exhaust does not burn through the headings, blow the headers and ruin all your hard work. I omitted that step in the cake shown here and payed the price for it. Because the Z-bombs are so close to each other, all ignitable material must be as insulated from fire and sparks as possible.

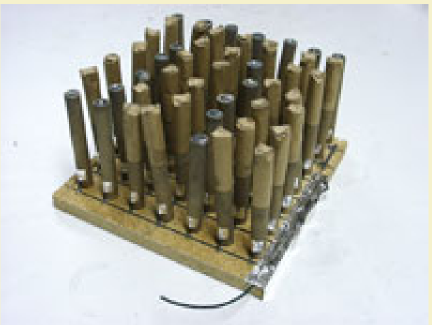

Figure 11: Foil tape used to seal and protect the black match ignition strip.

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Volume 2, Issue 5

Build This...

Insert Shells

May, 2002 Issue

Build This:
Insert Shells

Technique:
Making Black Match

Tool Tip:
Build a Black Match Frame

Technique:
Rolling Quickmatch Pipes

NEW! Glitter Simulator

Summary:
Small shells that are packaged inside larger shells, also called pupadelles or granatine by some Italian writers, open up a wide range of effects to the pyrotechnist. The 1-1/2" variety described here will fit snugly as rings of seven inside five inch shells. They may also be fired singly or in cakes much the same way as film canister shells are. The method of construction shown here is a variation of the traditional method described in the Fulcanelli article of Pyrotechnica XI.

Materials:

- (1) 5" x 8-1/2" 70lb virgin kraft, grain short
- (1) 2-1/2" x 8-1/2" manila folder paper
- (1) 4-1/2" x 9-1/2" 30 lb kraft
- (1) 1" piece of cross match
- (1) 1-1/2" piece of cross match

Tools:

- 1-1/4" x 6" long dowel
- Cross match punch or awl
- Rubber mallet
- Anvil cutters

Unmeasured Materials:
Coil of chinese time fuse, 4FA, 1/4" stars, white glue, flax twine, wheat paste

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1-1/2" Insert Shells...

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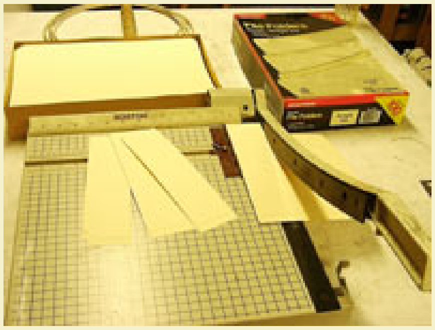

Figure 3: Cutting file folders with a paper cutter.

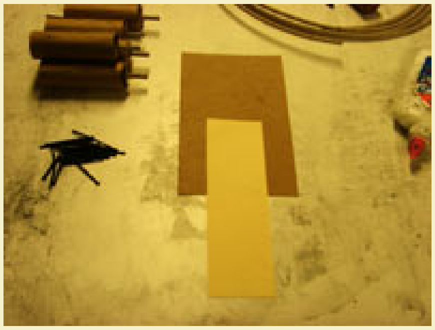

Figure 4: Paper placement for rolling the cans.

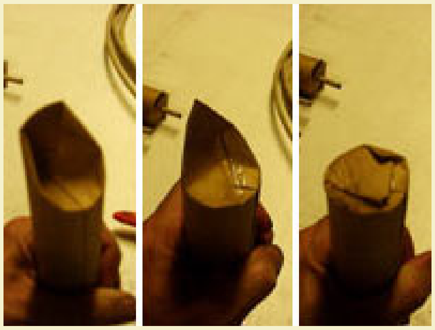

Figure 5: Making the triangle fold.

Introduction:

Small insert shells, as the name implies, are typically inserted as a component of larger shells. When the primary shell breaks, the smaller shells are thrown out in a circle where they produce a striking ring of secondary smaller breaks. These miniature shells, often called pupadelles (pronounced "poop-a-dell", a word derived from the Italian word for puppet), must fit snugly in the ring in order to be dispersed symmetrically.

The method shown here for making these shells does not require prefabricated tubes of any sort, which allows the builder to adjust their diameter to fit the desired shell they will be used in. There is another method that employs small paper cans with end caps that are much quicker to produce, but you must have a source for the right sized cans with matching caps. Even quicker to produce are the small plastic canister shells made for this purpose, but again you must have the right size for your application. If nothing else, the traditional method shown here allows you to whip up a batch of inserts in a pinch in case you don't have any plastic shells on hand.

Construction:

This type of insert shell resembles a stripped down version of full sized canister shells. There is a case, a liner, time fuse, spiking and a paste wrap. About the only thing they don't have are end disks. The inner liner material is much thinner than the chip board used for typical canister shells. Manila file folders are the ideal thickness. Poster board can also be used, although the resulting shell will be slightly larger than if file folder paper is used. Figure 3 shows how a paper cutter can be efficiently used to make short work of file folders. The folders are cut into 2-1/2" wide strips, which are then cut to 8-1/2" lengths.

The file folder liners are placed on a strip of 70lb kraft that measures 5" by 8-1/2" long, with the grain running in the short direction, as shown in Figure 4. It helps to put a little white glue under the liner where it overlaps the kraft paper, which prevents the liner from sliding off center when the case is on the former. A 1-1/4" dowel rod with a 5/16" hole drilled in one end is used to roll up the case.

With the case still on the former, slide it so that the end of the dowel containing the hole is level with the edge of the inner liner. The kraft paper that overhangs beyond the edge of the dowel is now crimped closed using what is called the "triangle fold," illustrated in Figure 5. I prefer to apply a little white glue between the folds to help reduce the ability of the ends to blow out instead of the sides, although many builders skip this step.

Next a center punch is used to punch through the folded paper and into the hole in the dowel rod. The time fuse should fit snugly into this hole when it is

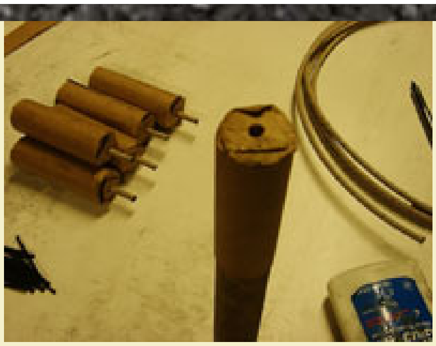

Figure 6: Fuse hole punched.

removed from the former. Before sliding the case off the former, the end can be flattened down by inverting the dowel onto your workbench and giving it a couple whacks with a rubber mallet. The case is now ready for fusing.

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1-1/2" Insert Shells...

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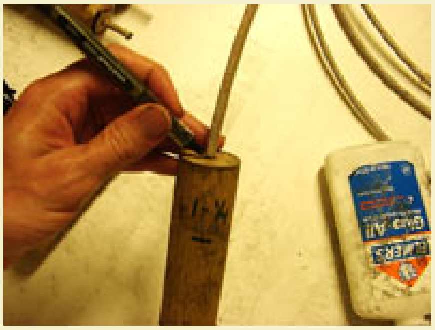

Figure 7: Using a length gauge to mark time fuse.

Due to the small size of this shell, it would be difficult to insert a piece of cross matched time fuse down into the casing from the inside. The clever solution devised to get around this problem is shown in Figure 8. Working from a full roll of time fuse, a mark is made 1-3/4" from the end where it is to be cut (this assumes 1-1/4" between cross match centers and should be altered to produce the desired timing for your application). One time saving trick is to have the 5/16" hole in the dowel rod bored to the same length as the time fuse length. This gives you a simple gauge for quickly and consistently marking you time fuse, as shown in Figure 7. Several dowels could be prepared with various length holes corresponding to your most commonly used insert shell timings.

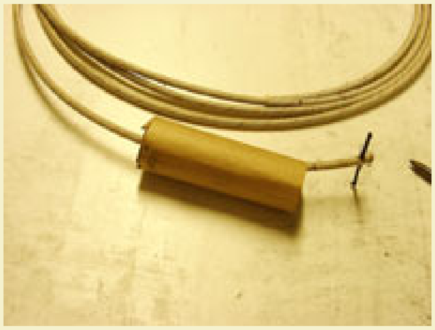

Figure 8: Case threaded onto time fuse coil and crossmatched.

The casing is now slipped onto your time fuse coil so that the fuse runs all the way through it. The end is now punched and cross matched 1/4" from the end, as shown in Figure 8. After the cross match is secured, the time fuse is simply pulled back into the case until the cross match hits the end. The fused assembly is then cut free at the mark you made, as pictured in Figure 9.

You should now have a fused casing that is ready for loading, as shown in Figure 10. It is a good idea to run a bead of white glue or woodworkers glue around the joint between the time fuse and case in order to help prevent gas leaks in this area. The glue should be allowed to dry before proceeding further.

A wooden block with a hole drilled through it to accommodate the time fuse makes a handy fixture to rest the shell on during the loading process.

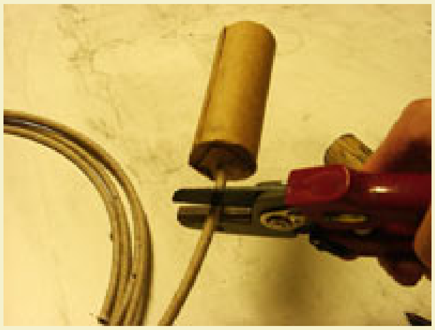

Figure 9: Time fuse is pulled through and cut where marked.

Because the walls of the shell are thin and there is not much integrity to the casing, they must be filled solid to avoid being crushed from the pressure that builds up during the break of the parent shell. This requirement, combined with their small size, makes the use of flash bags difficult as a burst mechanism. Thus, they are simply filled with a mixture of 1/4" stars and 4FA black powder. The case is filled half way with stars, then a quantity of 4FA is poured over them and jostled until it fills in the voids between the stars. The shell is then filled the rest of the way with stars and more black powder in the same way, making sure not to fill beyond the edge of the inner liner.

Once the shell is loaded, another triangle fold is used to close the bottom, which should look like Figure 12. At this point the shell is ready for spiking.

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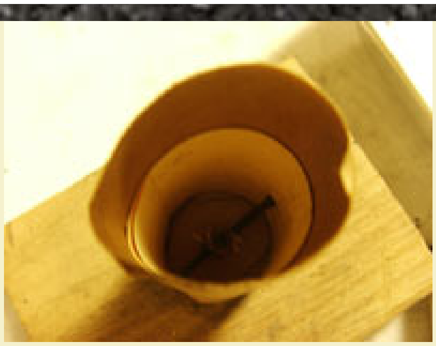

Figure 10: Cross matched end sits flush against bottom of can.

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1-1/2" Insert Shells...

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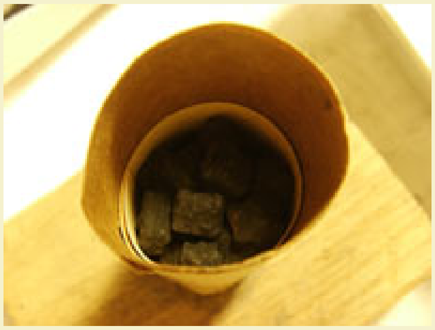
Figure 11: Filled with 1/4" cut stars.

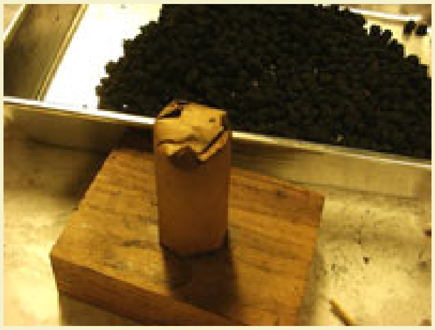
Figure 12: Bottom is triangle folded.

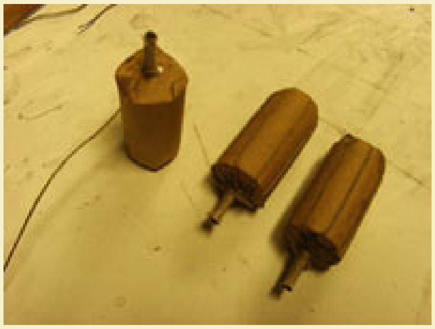
Figure 13: Spiked with 8 vertical strands of flax twine.

The spiking pattern shown here has been developed to work with the specific type of paper, twine and homemade burst charge I use, and may not be ideal for different materials. The twine used is a good strong flax twine that does not stretch under tension. Eight verticals are used in order to strengthen the shell in its weakest areas, which are the two folded ends. No verticals are used in order to insure that the sides of the shell burst instead of the ends. Adding horizontal spiking with this type of twine also causes the shell to break too hard and blow the stars blind.

Two turns of pasted 30lb kraft are applied to the shell in order to fire proof them and keep out the hot gases generated when the parent shell breaks, which could prematurely set them off. The ends of each time fuse should be protected with a piece of masking tape, which will prevent paste from getting onto the exposed end and absorbing into the powder core.

Figure 14 shows a good method for pasting many shells at once. A stack of kraft sheets are laid out on the table in a stair stepped pile, with paste between each sheet. About 20 sheets can be stacked up in this way, then the entire stack can be broken in at once by crumpling it up and working in the paste. The stack is then flattened out and each shell is rolled off the top of the stack. The feathered edges make each sheet easy to grab, eliminating the hassles of prying apart each single sheet.

When rolling the shell in the pasted paper, the overhanging paper at both ends can be folded down as you go. This will seal the ends without the need to tear and pleat down the paper. The wrap should be twisted around the time fuse to provide a good crown.

Once dry, the time fuses are punched and cross matched 1/4" from the end. The shells are now ready to be loaded into shells or fired from small mortars. When testing shells of this size, it is easiest to bottom fuse the mortar with visco and prepare tiny lift charges of 15g wrapped in a square of tissue paper and twisted closed. To fire the shell, simply insert the visco, drop in a lift packet followed by the shell and you are ready to go.

Shells of this size are difficult to break with a good pattern. If you are not using the exact same materials described for this article, you will have to adjust the spiking pattern until you get a good break. It is not unusual to run a half dozen trials trying to dial in the break on these little shells. If you are blowing out the ends, you can reduce the horizontal spiking or eliminate it altogether as I have done here. If you are using cotton, make sure you paste the string well. If you are looking for a bigger spread, you can try adding whistle mix or flash in with the black powder burst, or increasing the horizontal spiking. It will take some experimentation to find what works best for you. But then that's what makes this hobby fun!

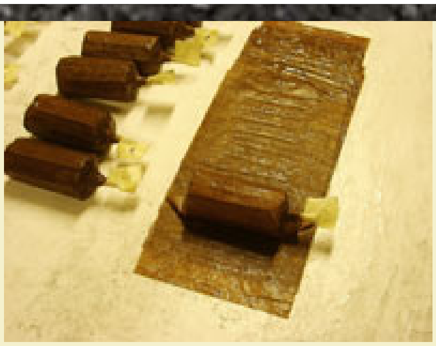

Figure 14: Final paste wrap.

References:

Traditional Cylinder Shell Construction, Part 2 by A. Fulcanelli, Pyrotechnica XI

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4" Mine w/Saettines

Page 2

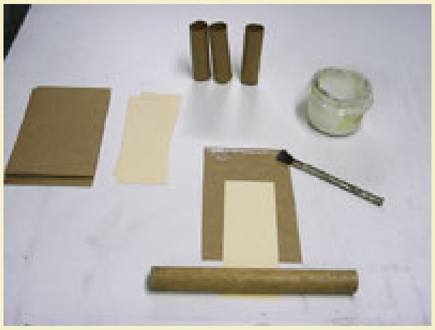


Figure 1: Paper cut and ready to roll saetine cases.

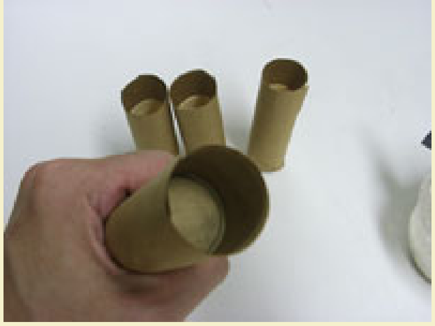
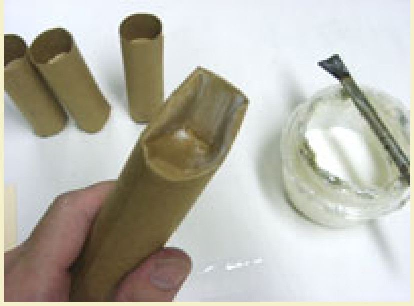


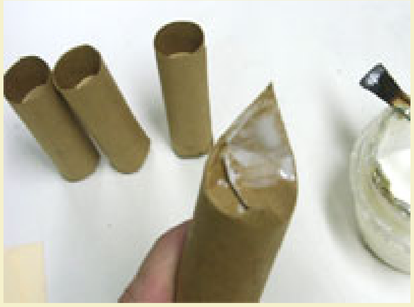
Figure 2: Dowel even with tag board prior to folding the overhang.

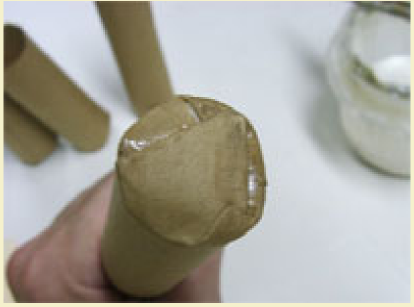
Making the Saettines:
Saettines, also spelled siatenes or citeens or alternatively called lambetti, are a type of small report used in shells and mines. What sets them apart from other types of reports is the method by which they achieve their delayed timing. The simple paper casings are only partially filled with flash powder, into which a single strand of good quality black match is inserted. The remainder of the space is rammed with sawdust or bran such that it surrounds the black match and prevents the gasses from shooting along the sides as in piped match. This creates a reliable delay that, while not as accurate as time fuse, does the job quite well when a random barrage of salutes is desired following a color break shell or colored star mine.

Saettines are quick and easy to make, since they require no special tubes, disks or time fuse. The ones described here will measure 1" diameter by 2-1/2" long. You will only need seven to complete the 4" mine for this project, but you might as well make a good number of them because you will find yourself wanting to use them a lot and of course in fireworks, more is always better!

The case for saettines are made by rolling two pieces of paper together at once. An inner liner is made from thin chip board or manila file folder paper measuring 2-1/2" wide x 7" long. This will give you two turns around a 1" diameter case former. One 14" legal size file folder will give you enough strips to make a dozen saettines. The outer strip of paper shown in Figure 1 is a piece of 70lb kraft measuring 4-1/2" wide by 7-1/2" long, with the grain running in the short direction. The liner is placed over the kraft so that it overhangs a few inches on the end you are rolling from. The kraft is glued at the edge and the two sheets are rolled up together.


Step 1: Making the triangle fold


Step 2: Second fold.


Step 3: Third fold.

Both ends of saettines are closed by a simple fold known as the "triangle fold." The case former is slipped down so that it is level with the inner liner. Steps 1-3 above shows how the overhanging kraft paper is folded to form the bottom of the saettine. I like to apply glue after each fold to help the pleated paper stay down. After the last fold is made, place the bottom of the case on a table and rap the case former with a rubber mallet to make the end good and flat.

As you might guess, this folded end plug is not reliably gas tight. While some claim that proper construction results in a good seal, having your shells detonate from a gas leak in one single saettine is not the best way to verify this claim. There are two methods commonly used to guard against gas leaks setting off your saettines. One is to ram an initial scoop of sawdust into the bottom of the case prior to loading the flash. The other is to paste a small square of lightweight kraft over the bottom of the case after it is loaded. I personally prefer the latter method.

Begin loading your cases by bundling them together and inserting a 5" stick of black match in each one. The quality of your black match is important, since only one strand can be used. Using multiple strands will cause a fire gap between them that will ruin the delayed effect.

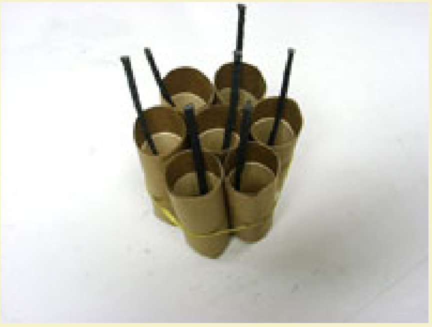


Figure 3: Bundled and fused cases ready to load.

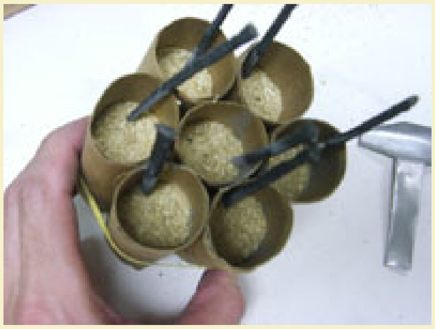
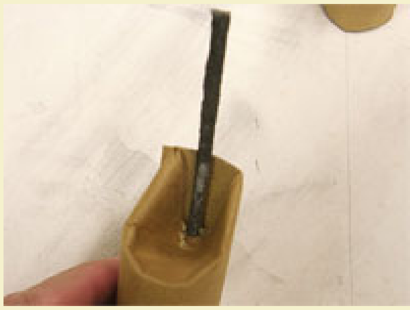
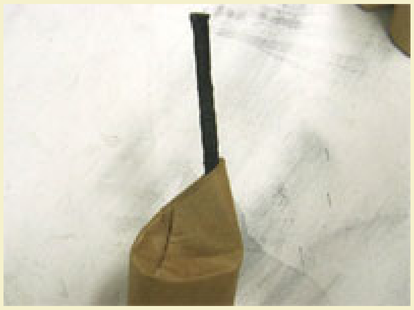
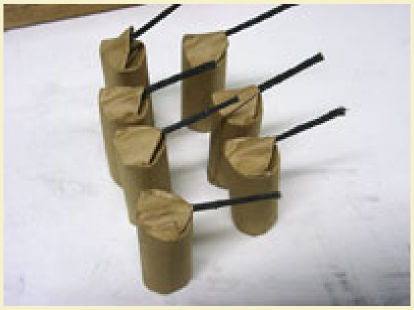


Figure 4: Packing in the sawdust for delay.


Step 1: First fold


Step 2: Second fold.


Step 3: Third fold.

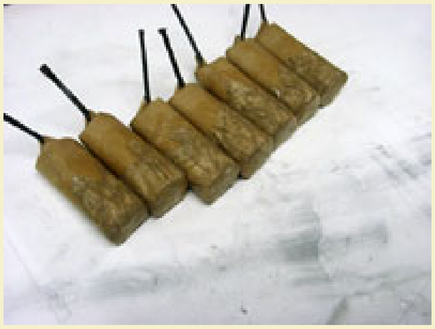


Figure 5: Pasted paper over bottom protects against gas leaks.

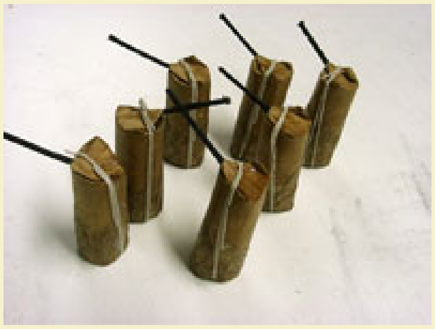


Figure 6: A clove hitch made with pasted cotton twine secures the ends.

Next load the flash powder into each case, leaving anywhere from 20% to 50% unfilled depending on how much delay you want. The unfilled space is then loaded with sawdust and tamped down to form a tight seal around the black match, which should run down the side of the case as seen in Figure 4. Note that while this consolidates the flash, it does not effect the performance of the salute. This reality is contrary to the belief sometimes held that salutes should contain only loose flash with some air space around it.

The next series of photos above shows how the triangle fold is made around the protruding black match, only this time no glue is used. Figure 5 shows the pasted kraft paper gas seal around the bottom of the loaded saettines. Omit this step at your own risk!

The saettines are finished by looping a clove hitch around the case to hold the ends down. Cotton twine wetted with wheat paste makes a good cinch when tying them off. Allow them to fully dry before loading them into any mines or shells.

WARNING: saettines are only to be used as components of other shells or mines and should never be used as hand held ground bombs. Salutes of any type using black match as the ignition method should never be lit by hand, especially when holding them!

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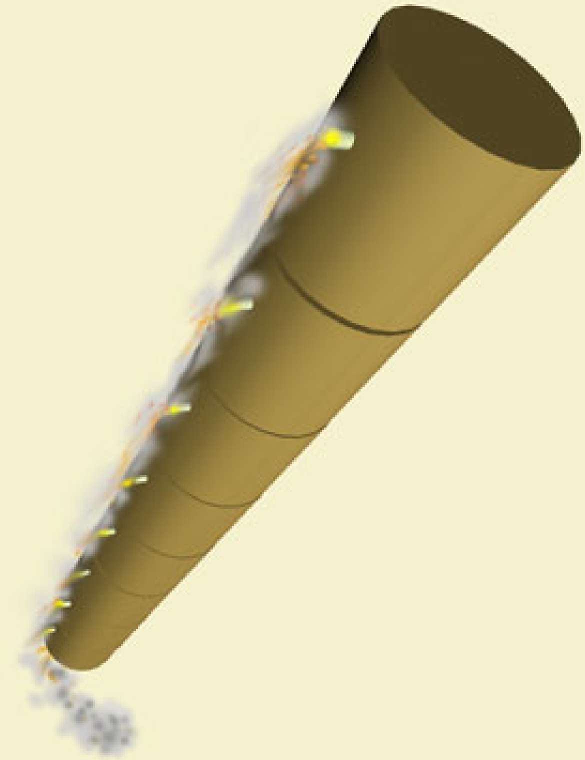
Volume 6, Issue 2

Build This...

4" Eight Break Piled Shell

by ***Kyle Kepley***



April, 2006 Issue

Build This:
4" Eight Break Piled Shell

Beginner Project:
1-1/4" Microstar Gerbs

Technique:
Casting Milling Media

Tool Tip:
Large Case Formers

Autopsy:
4" Mine

Summary:

This eight break exhibition shell uses a rarely seen trick to obtain short delays between breaks without the risk of chain reactions from spolette blow-through. While the construction technique is a bit unorthodox, the piled shell method produces a very fault tolerant shell that can survive several different types of failures and still perform with minimal detraction. The shells shown built here were fired in the 2005 PGI competition and took second place in the Best Medium Cylinder Shell category.

Materials:

- (36) 3-3/8" diameter 1/8" thick chipboard disks
- (7) 23" long x (shell height + 3") wide poster board
- (7) 23" long x (shell height + 4") wide 60 lb kraft
- (1) 23" long x (shell height + 7") wide poster board
- (1) 23" long x (shell height + 8") wide 60 lb kraft
- (8) 23" long x cut to size 30 lb paste wrap strips
- (1) 36" long x cut to size 60 lb final paste wrap
- (1) 36" long x cut to size 30 lb outer dry wrap
- (1) 3" tall x 2-1/2" dia. bottom shot w/2 sec delay
- (8) 2" long x 1/4" I.D. x 1/2" O.D. pipette tubes
- (208) 3/4" comets
- (1) 4" long stick of thin black match"

Tools:

- 3-3/8" dia. case former
- hot glue gun
- awl
- thin, sharp knife
- spiking horse
- Maltese shell roller
- 4 strand twine dispenser

- (1) 3-1/2" plywood disk with notch
- 150 g 1/8" rough powder lift (ball milled)

Unmeasured Materials:

7:1 KP rice hulls, Chinese time fuse, flax twine, cotton twine, fine sand, 1/4" rough powder, 2Fg BP, meal prime slurry, wheat paste, white glue, hot glue, tissue paper, 3/4" wood wedges, newspaper, fiber tape, quickmatch leader

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Volume 6, Issue 2

4" Eight Break Piled Shell...

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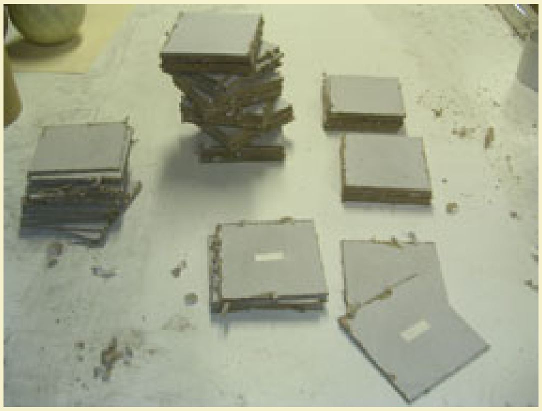

Figure 1: Taping blocks of six 1/8" chipboard squares together with double sided carpet tape.

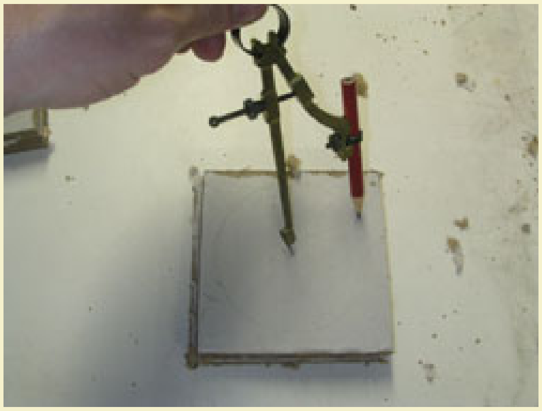

Figure 2: Using a compass to draw a 3-3/8" circle on the top disks.

Introduction

Smaller diameter shells with six or more breaks, also known as "fence post" shells for their long narrow profile, have been an ongoing quest of mine for quite some time. These shells present a unique challenge in that the more breaks you have, the shorter the timing must be between them in order for them all to complete before hitting the ground. The standard practice is to begin breaking the shells almost immediately after the shell leaves the mortar, such that you have breaks going off for the full rise time of the shell as well as the fall time.

There are several aspects that make this type of shell difficult to achieve. The long, narrow body of the shell is more subject to breaking in half during the lift. The long size also makes construction a bit tricky, although the method used here makes it pretty simple. The weight of the shell puts a lot of pressure on the bottom breaks, making flowerpot failures a lot more difficult to prevent. The number one challenge, however, is to achieve the rapid timing between the breaks. Short delays means short spolette charges, which are notoriously difficult to keep from blowing through. An eight break shell would need no more than a 3/8" charge of fast burning BP in the spolette tube, which isn't much to stand up to the large pressure generated inside a shell before it breaks. Thus the most common malfunction in fence post shells is blow through from one break to the next, resulting in chain reactions where several breaks go at once. I've actually had all eight breaks go at the same time in some cases, while other times three or four went as a group.

One way to deal with the blow-through problem is to use weaker break charges in the shells. Anyone who has ever seen Jim Freeman's eight breaking three inch shells at PGI competitions may have noticed that the breaks seem to have less spread than what you would normally expect from a 3" shell. It is very difficult to use a hard-hitting, flash-enhanced break charge in a multi-break that only has 3/8" or less of spolette charge.

I've tried all manner of spolette construction in the quest to find one that can hold up to a hard hitting 4" comet shell, but never came up with a reliable solution. The most common method is to ram an oversized charge and then drill a small diameter hole into the charge to get the proper amount of timing. The best results I have had were from ramming a 3/8" I.D. thin walled recycled kraft tube with a charge that bulged the tube wall, then combining the drilled back technique with a clay bulkhead on the end that passed fire into the next break. The same method used on smaller I.D. spolettes using much stronger tubes had a much larger failure rate. The harder tubes were not able to hold the contents as well as a bulged out recycled tube,

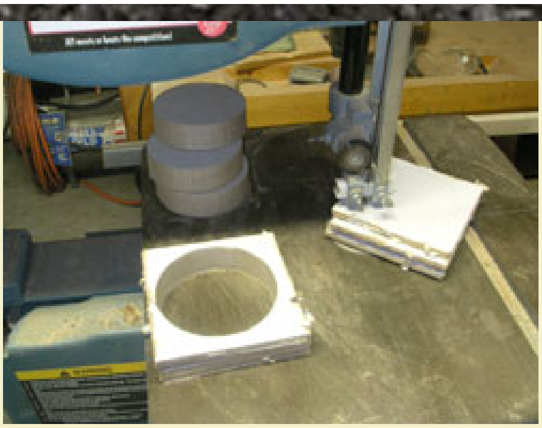

Figure 3: Cutting six disks at a time with a band saw.

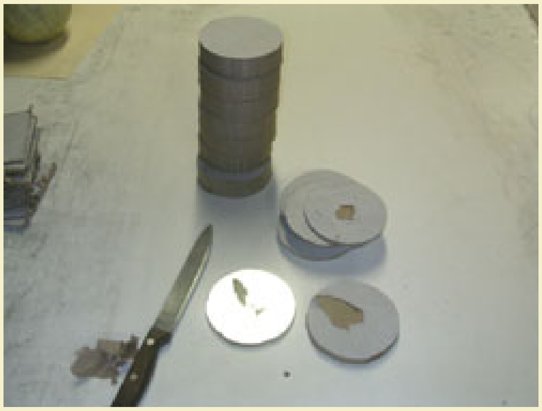

Figure 4: Separating the disks after cutting.

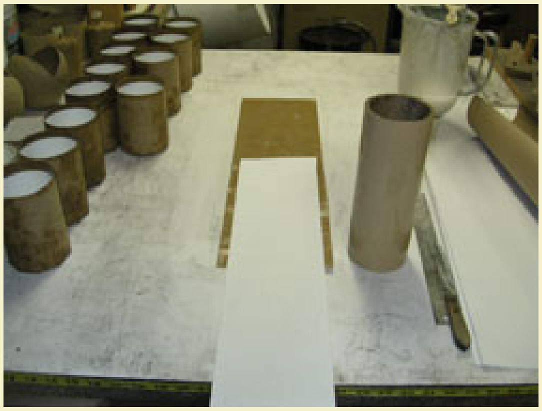

Figure 5: Rolling the shell cans.

which is contrary to the common notion that only rock hard tubes should be used for spolettes.

After several years of trying to make an eight break shell with respectable, hard hitting breaks, I decided that the basic design of chained multi-breaks was an unreliable method for doing this. I decided to revert to an alternate construction method known as "piled" multi-breaks. A piled shell is any multi-break where all breaks take fire at the same time when the shell fires from the mortar. The most common piled shell is the "peanut shell," which is two ball shells attached together with their fuses linked together, which take fire from the lift charge. Ball shells are difficult to stack in numbers greater than two breaks however, so you rarely see more than two piled ball shells.

Piled shells solve a lot of problems, although some would consider this method "cheating" since the whole spolette challenge is avoided. Piled shells are very fault tolerant. If a piled breaks in half on the way up, everything still functions without any but the most astute audience member noticing. If one shell fails to take fire, it doesn't break the chain and terminate any further breaks the way a traditional multi-break would. If one break flowerpots during lift, the others will usually survive and perform as expected. A piled shell can also be constructed with the bottom shot located at the top end of the shell relative to how it is loaded into the mortar, thus keeping the most destructive break at the least stressed end of the shell. Traditional multi-breaks require the bottom shot to be at the bottom of the shell chain, thus exposing it to the most lift forces and resulting in destruction of the entire shell (not to mention the mortar) if there is a gas breech. Piled shells also allow you to use extremely short durations between breaks that simply would not be possible with a spolette. The shell described here uses one half second timing between breaks, which would require something like a 3/16" spolette charge!

There are some timing limitations to the piled shell method when using commercial timed fuse as the timing mechanism, since the time span from lift until when the last break fires will be dictated by the longest segment of time fuse that can fit sideways in your shell. The eight break described here pretty much pushes this limitation as far as it can go, with a pretty rapid timing between breaks such that the eighth time fuse in the last break actually spans the entire width of the shell! If you were ramming your own side-mounted spolettes, however, you could get around this limitation by just using a slower burning delay composition.

Now, I know some old-school traditionalists are going to pooh-pooh this unorthodox construction method as being a glorified case of "double loading" stand alone shells. But if you want to have eight breaks of hard hitting comet shells fill the sky at a comfortable height in the span of about five seconds to completion, I challenge anyone to pull it off with the traditional chained spolette method!

Construction

This shell consists of eight breaks built using a combination of Maltese, Italian and Oriental shell building techniques. The cans are produced in the Maltese style, which are fast to produce and result in a good break. The shells are also loaded using wedged comets like a Maltese break, while the fusing is piped into the side similar to how Chinese ball shells are made. The spiking is the Italian style, while assembly and lift are in the Maltese style. I guess you could say this shell is pretty multi-cultural!

The pictures shown here actually illustrate two 8-break shells being built side by side, which were fired as a pair in the PGI competition of 2005. So you are really looking at twice as many components as you would actually need to build just one shell.

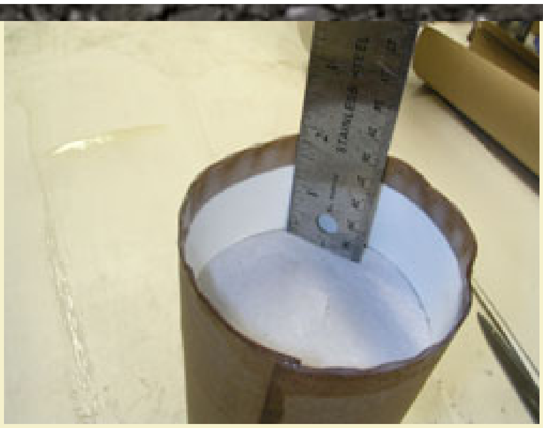

Figure 6: Leaving 1.5" of poster board above the end disk.

Making End Disks

When building overly long shells such as this one, the standard shell diameters can result in shells that have difficulty fitting into the mortar. The various breaks never align with great precision, and small alignment offsets can result in irregularities that prevent the overall shell from fitting smoothly into the mortar. This tight fit also results in more stress on the shell when it is fired, especially if an overly long gun is used.

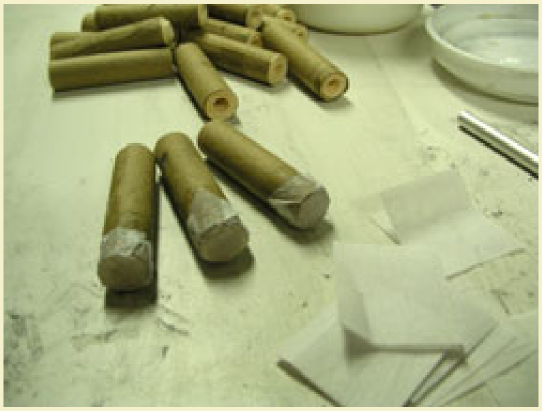

Figure 7: Preparing the internal pipettes.

There are two ways to solve this problem: use an oversized mortar or build an undersized shell. Since it is inconvenient to have to drag a custom steel mortar around with you whenever you fire this shell, the undersized shell solution is used. The shell I.D. is reduced by 1/8", which means you will need a 3-3/8" case former and matching end disks to build the shell.

Case formers do not have to be fancy solid wood pins with handles on them, you can use any smooth cylindrical object that is the right diameter. For this shell I used a segment of cardboard mailing tube that happened to be 3-3/8" O.D., then wrapped a few turns of plastic packing tape around the outside in order to protect the cardboard from paste during use.

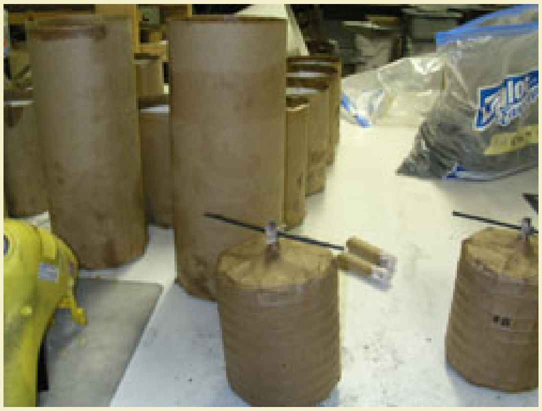

Figure 8: Cross matching the bottom shots with extra long match.

This shell requires 36 end disks of 3-3/8" diameter, which is an odd-ball size that you might not be able to find at a typical hobby pyro supplier. I opted to cut my own disks from 1/8" thick thermal insulation board commonly sold as 4ft x 8ft sheets in many home supply centers like Home Depot or Lowes. The board is recycled chipboard with a silver foil coating on one side and white paint on the other side.

The board must be cut up into 36 rough squares that are about 4" on a side. If you are using hand tools like a circular saw or jig saw to cut the squares, don't worry about being sloppy with the cuts. The squares are over sized so that you have room for slop.

The squares are then stacked into groups of six as seen in Figure 1. A small piece of double sided carpet tape is used between the squares in order to hold each stack together. Stacking the squares in this way allows you to cut six disks at once, such that you only have to cut out six circles on a band saw instead of thirty six circles. The tape is there to insure that the disks don't slide around while you cut them.

Use a compass to scribe a 3-3/8" circle on the top disk of each pile, as seen in Figure 2. A band saw with a 1/4" wide blade is then used to cut out the circles six at a time as seen in Figure 3.

Once the disks are all cut, a knife is used to separate them from each other and the strips of carpet tape are pealed off. The process is not quite as bad as you would think, I think I made 72 disks for this project in about one hour. A table saw or panel saw can make short work of cutting the large sheet in to 4" squares, which is probably the most time consuming part if using hand tools.

More...

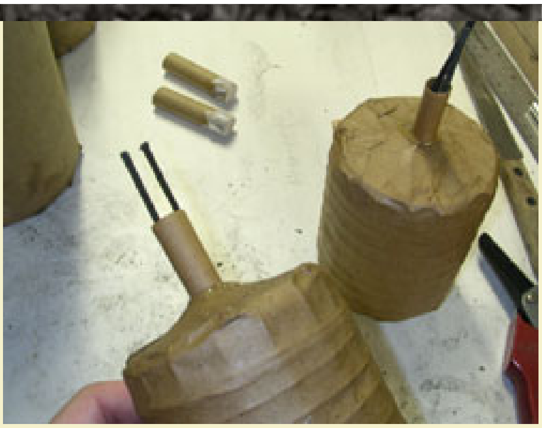

Figure 9: Holding the match with a retaining tube to keep it centered.

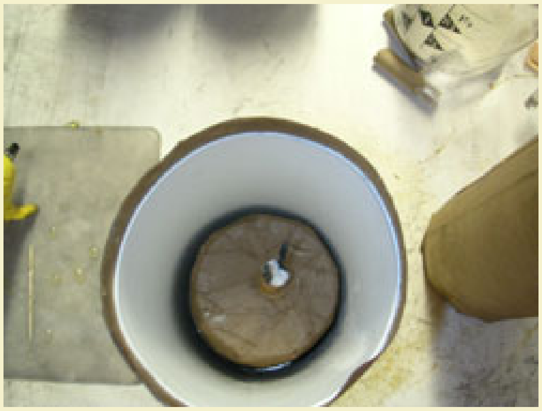

Figure 10: The bottom shot loaded into the last break.

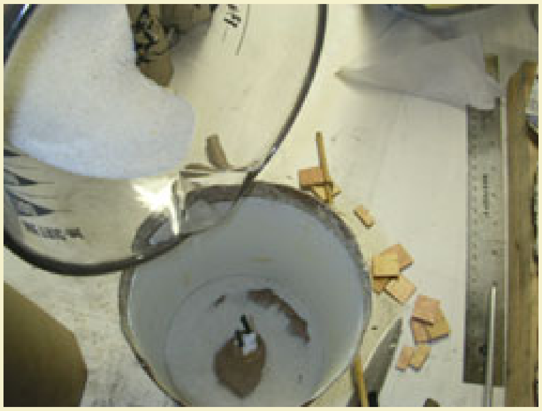

Figure 11: Dusting in the bottom shot with sand.

4" Eight Break Piled Shell...

Page 3

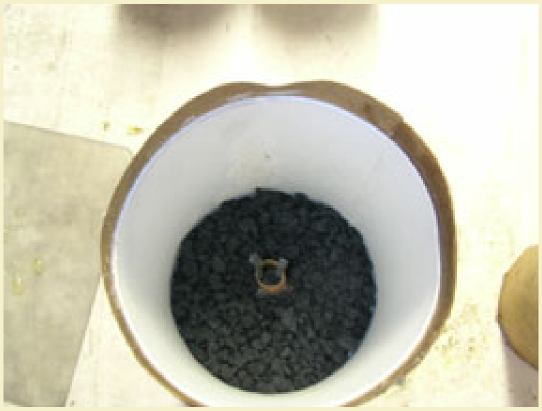

Figure 12: Placing a layer of rough powder on top of the bottom shot.

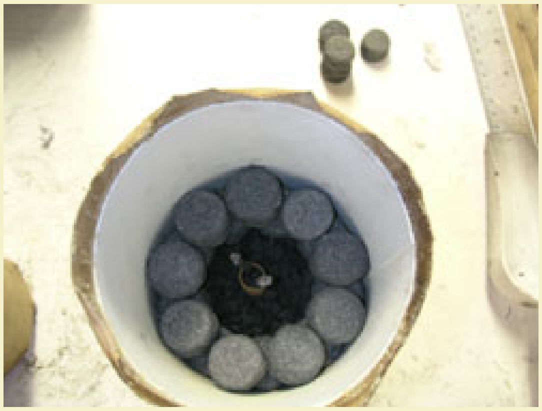

Figure 13: Loading two rows of comets on top of the rough powder.

Preparing the Components

Because the shell casings are best loaded while they are still damp after pasting, it is necessary to prepare all the internal components prior to rolling the casings. This includes eight time fuse tubes, a tray full of 7:1 KP on rice hulls for the burst charge, about 50 3/4" x 3/4" wooden wedges, some 1/4" rough powder, a 3" bottom shot made as described here and 208 3/4" comets of your choice. To make the shell exactly as the one built here, you would need 72 mag red comets, 72 mag green comets and 64 silver glitter comets. All comets are primed in a star roller using 40 parts meal powder to 1 part medium flake bright aluminum or something close to that. Priming 3/4" pumped stars in a star roller, preferably the tire type, goes very fast but does leave a lumpy prime that creates slight variations in star size. Since there are only three rows of stars used in each break, the varying heights do not cause much of a problem.

The time fuse will not be inserted into each break until the entire shell is assembled and pasted in. In order to make inserting the fuse easier, an internal pipe is put into place that will accept the time fuse and guide the ignition fire to the center of the shell. These pipes should be 1/4" I.D. and about 1/2" O.D. with a length of 1.5". One end of the pipe is covered with a square of pasted tissue paper so that the burst charge can not migrate into the pipe after the shell is loaded.

It is important that these pipes are pasted or glued with a 50/50 white glue/water mixture when rolling them. A dry rolled tube can cause big jamming problems when a tight fitting time fuse is inserted, and it is difficult although not impossible to fix when it happens.

Making the Cans

The shell casings are made using the wet rolled Maltese method, which is actually faster than dry rolling and pleating in the Italian style. The breaks will contain three rows of 3/4" comets, thus you need to know the height of your comets so that you can produce a casing of the proper height. You can always produce an overly long casing and trim it down later if you like, but it is less work to just get it right to begin with. It is best to produce and prime your comets first, then measure three of them end to end. Add a quarter inch to this measurement and this will be the inside height of your break. Add three more inches to this number and this will be the width of the poster board you need to cut. The width of the kraft strip needs to be equal to the width of the poster board plus an additional half inch. Both the poster board and the kraft strip should be 23 inches long.

The eighth break of the shell will contain a 3" bottom shot in addition to the three rows of comets, so a longer can needs to be rolled for this one. The bottom shot should be completed prior to rolling the 8th break casing. The height of the completed bottom shot is measured and added to the dimensions determined for the other casings.

The cases are formed by first brushing paste onto one side of the 60lb kraft strip, then overlaying the poster board by half as seen in Figure 5. The first turn of poster board is wrapped around the former, then paste is brushed onto the remaining area of poster board. The casing is then rolled up the rest of the way.

An end disk is dropped into one end so that 1-1/4" of poster board extends above it, as seen in Figure 6. If you made disks using the thermal insulation board, the silver side should face downward. A more detailed description of how to close the can be found here. The edges are sliced into tabs with a thin, sharp knife, then the kraft is separated from the poster board. The poster board tabs are folded down, then a second disk is placed on top. The kraft tabs are then folded up over the disk to hold it in place, brushing on extra paste as needed.

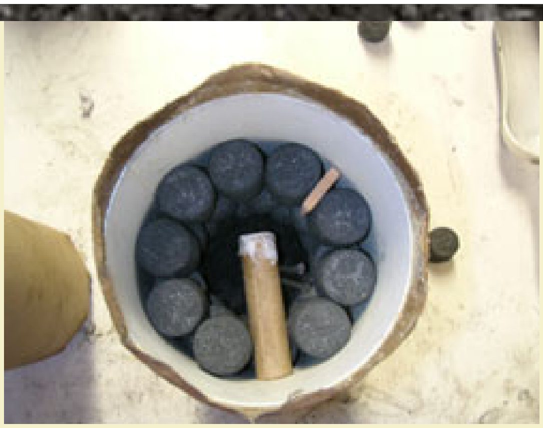
Figure 14: The third row of comets contains the pipette glued to the shell wall.

Loading the Comets

While the cans can be loaded after they dry, it is actually best to load them right after rolling them while they are still wet. The cans do not need to be fully loaded, only the three rings of comets should be loaded. Comets that are loaded into a damp casing will be firmly locked into place as the casing shrinks around them while it dries. This will secure the rings a lot tighter than is possible by just shimming between the stars with wooden wedges. When using the wet load method, you don't need to even shim the comets very tightly. Just insure that there are no spaces between the comets and let the shrinking paper tighten them down into solid rings.

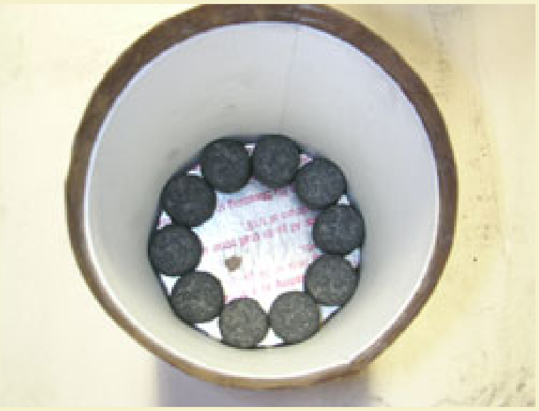
Figure 15: Loading comets into the single color break shells.

The eighth break containing the bottom shot is loaded by first inserting the bottom shot into the can and then filling around it with sand as seen in Figure 10 and 11. Note that the bottom shot is first cross-matched with an overly long strand of match, as seen in Figure 8. The match is then bent upwards and a small 3/8" I.D. tube is slipped down over the time fuse in order to keep the match strands pointed upwards. By guiding the extended strands of match up closer to the ignition point of the shell, the probability of ignition failure on the bottom shot is decreased.

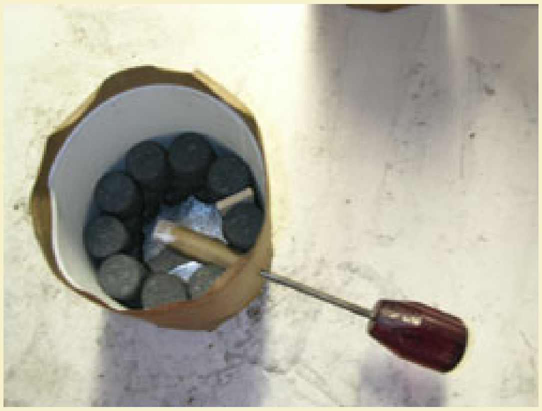
Figure 16: Punching the fuse hole through the shell wall and into the pipette.

The small space around the bottom shot and the shell case is to be filled with sand, as seen in Figure 11. Sand is preferable to sawdust since it is faster to load and it doesn't compress. Bouncing the shell on the table while pouring the sand will help to settle it down around the bottom shot. The sand is only filled just to the top of the bottom shot, then a layer of rough powder is added as seen in Figure 12. The three rings of comets are now loaded on top of the rough powder just as they are for the other seven breaks.

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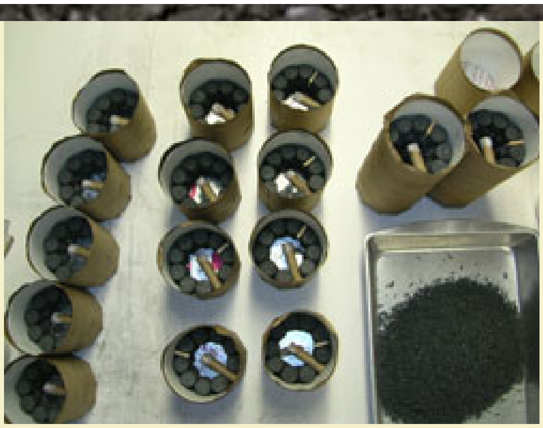

Figure 17: All the breaks are loaded, dried and ready for break charge.

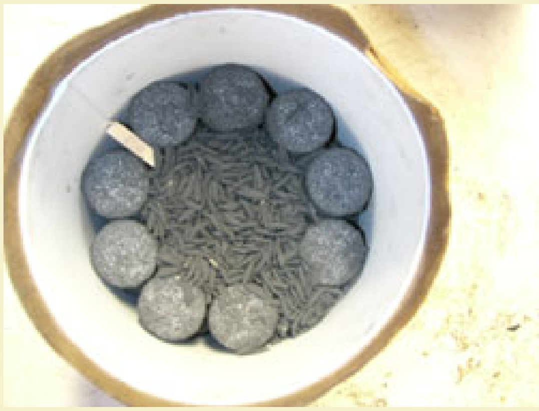

Figure 18: Close-up of shell loaded with 7:1 KP on rice hull break charge.

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4" Eight Break Piled Shell...

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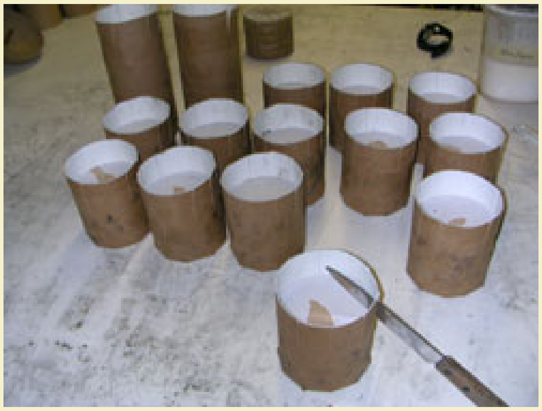
Figure 19: Slicing the tabs for closing the shells.

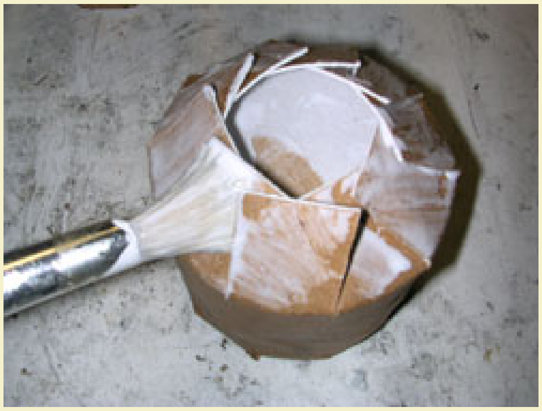
Figure 20: Tabs are glued and folded down over the end disk.

The shell shown here uses two rings of color comets with a third ring of silver flitter comets. The flitter comets add a nice coconut tree effect inside a ring of bright color comets, which alternate between red and green for each break. Thus you will need to mark the effect on the outside of each casing so that you can keep track of them as the shell progresses. All the comets look the same, so you need to be careful about labeling what is actually loaded into each shell.

When loading the third ring of comets, the fuse pipe will take the place of one of the comets. A ring of hot glue is run around the end of the tube so that it can be fastened to the shell wall. This ensures that the pipe will not fall out of place or get pushed into the shell when the time fuse is inserted. Figure 14 shows a fuse pipe in place, with the tissue covered end facing the inside of the shell. The tube should rest on top of the second ring of comets and be firmly wedged in with the third ring of comets.

Once the hot glue dries on the fuse pipe, an awl is used to punch a hole through the outside of the shell casing so that it enters the fuse pipe. This hole will be expanded later, but for now it is necessary to punch the hole so that the entry point for the fuse can be known later after the shell is closed and pasted.

Figure 17 shows all the cans loaded for two eight break shells. The cans are now set aside to dry before proceeding further.

If you loaded the cans while they were still damp after rolling them, you will find that the comets are firmly locked in place after the cans dry. In fact, it is not uncommon to actually see the comet pattern from the outside of the casing as the paper shrinks in tight around them-a sure sign that you will get nice round ring patterns.

The shells are loaded with KP coated rice hulls, with a coating of 7 parts KP per one part hulls. The hulls are the typical American flake type, which pack more densely than the Chinese whole-hull type (similar to puffed rice). The entire void remaining inside the shells are filled with this 7:1 charge, which will break the shells hard and round but still insure good ignition of the comets.

Closing and Spiking

Once the break is loaded into all the shells, they are closed as seen in Figures 19 through 21. A disk is dropped in on top of the loaded contents, then the overhanging casing is sliced up into tabs and folded down as seen in Figure 20. White glue is applied to the tabs and then a second end disk is applied over the end.

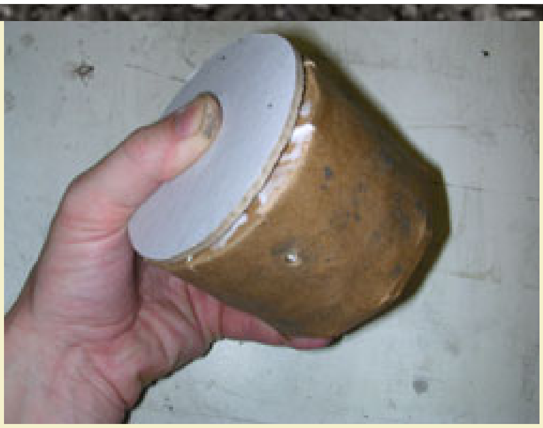

Figure 21: A second end disk is placed over the tabs.

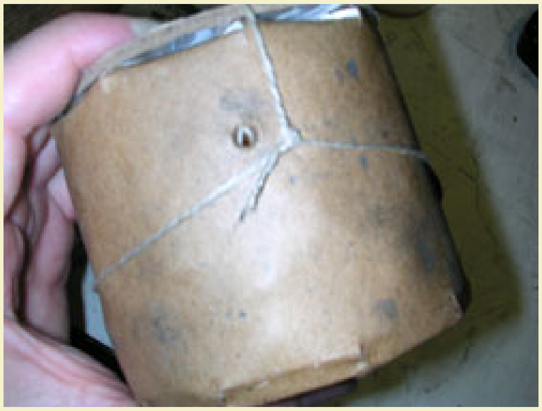

Figure 22: Starting the spiking twine with knot located next to fuse hole.

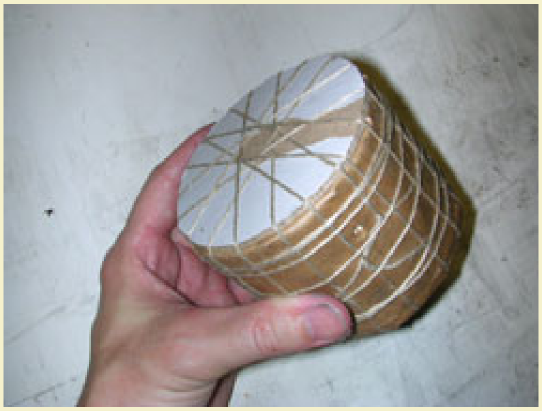

Figure 23: Off-center spiking used to spike the shell.

Because these shells do not have a time fuse sticking out one end, there is no convenient place to tie off the spiking twine. The twine must be tied around the middle of the case as seen in Figure 22. It helps to position the knot close to the fuse hole so that it is easier to find after the shells have been pasted in, since the knot will be visible but the holes will not be. For the shells shown here, the knot was consistently located to the right of the hole on every break. This way all you have to do is find the knot and then punch a hole to the left of it to relocate your time fuse hole after the shells are pasted in.

The twine used to spike these shells is the domestic six strand natural flax twine sold by PyroSupplies. This is similar to the Italian flax twine traditionally used on canister shells and is ideal for 4" and 5" canister shells. The spiking pattern used here is not real dense, only eight verticals and five or six horizontal wraps are required. The off-center spiking pattern is used in order to keep the ends as flat as possible. Keeping the ends flat by avoiding string pile-ups will reduce the gap between the breaks when the shell is assembled, which in turn reduces the amount of paper that has to be stuffed between the gaps and also reduces the chances of the shell breaking into pieces when fired. Interestingly, due to the design of this shell, it will still function correctly even if it does break into one or more pieces on the way up!

Pasting

Figure 24 shows all the shells spiked and ready for pasting. These will be pasted in with two turns of recycled 40 lb kraft paper. The recycled kraft actually produces a better gas-tight seal around the shell compared with virgin kraft, as it lays down better and seems to shrink tighter. This paste wrap does not play any role in confinement of the break, it is only there to fire proof the shell. The ends of the shell are pasted by tearing tabs in the overhanging paper and folding them down, as seen in Figure 26. The torn edges actually produce a better gas seal compared with cut edges, and it is quite easy to tear the recycled paper by hand. Since there is no time fuse to paste around, this process goes pretty fast.

Since you don't have a time fuse to mark with a tape flag to indicate the shell contents, you must be careful to sort your pasted shells according to effect while they are drying. Otherwise you will lose track of the effects in each shell. Once the paste wrap is dry, which doesn't take long in a drying box, you should mark each shell to indicate the contents.

Once the paste wraps are dry, it is time to punch holes where the time fuse outlets are. The thin 40 lb kraft should allow you to see the spiking twine pattern underneath, and hopefully you can locate the knots that serve as your hole markers. Once you locate the knot, poke around with an awl to find the time fuse hole, then use a pencil tip or reamer to clear the hole to it's full size, as seen in Figure 27.

More...

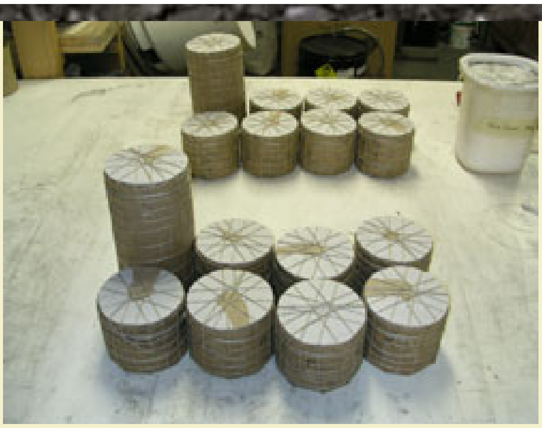

Figure 24: Two sets of shells ready for pasting.

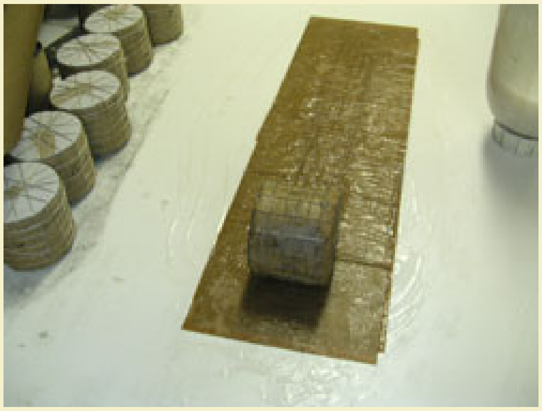

Figure 25: Pasting two layers of 30lb recycled kraft onto each break.

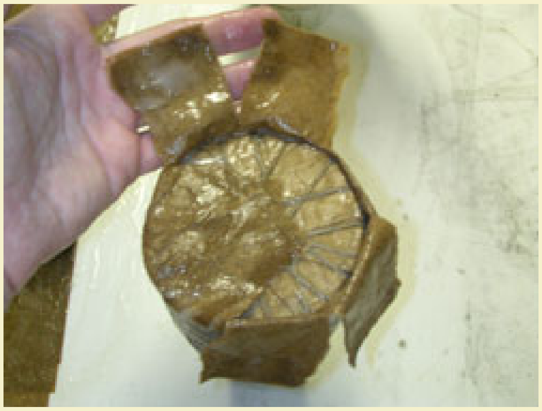

Figure 26: Ends are pasted by folding over tabs torn in the overhanging paper.

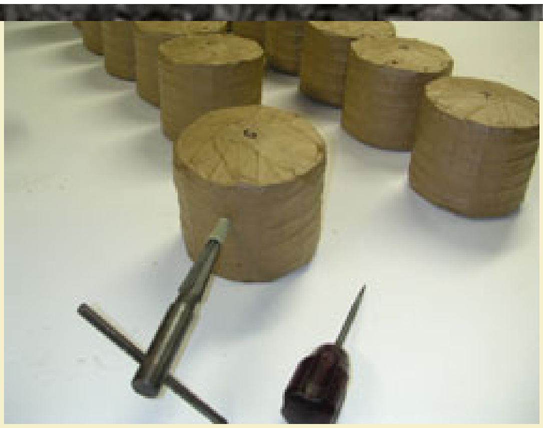

Figure 27: Re-punching the fuse holes after the pasted paper dries.

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4" Eight Break Piled Shell...

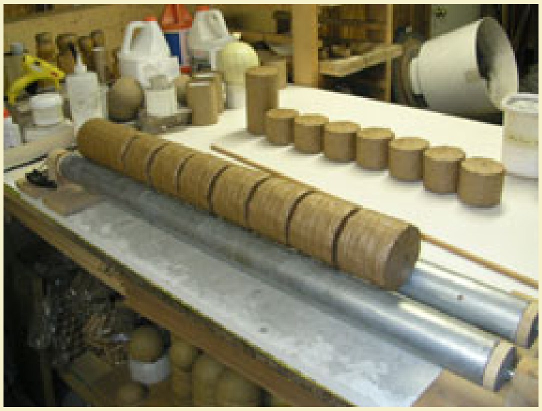

Figure 28: Aligning the shells on a Maltese Shell Roller.

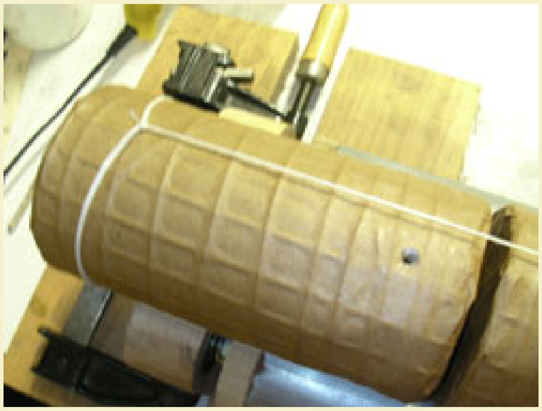

Figure 29: Starting the spiking twine at one end.

Assembling the Breaks

At this point we basically have eight independent shells, each of which could be fused and fired on its own. In fact, when this shell is fired, you still have eight independent shells, each with its own time fuse that ignites when the shell lifts and each performing independent of the other shells. We are merely binding all the shells together so that they can be loaded and fired as a single unit. This is actually not all that different from "double loading" eight shells on top of each other. For those not familiar with the practice known as "double loading," this is a technique where a second shell is loaded on top of the first shell loaded into the mortar, except the second shell has its lift bag and leader removed. The lift from the bottom shell also lifts the second shell while simultaneously igniting its exposed time fuse. Normally this is only done with smaller diameter ball shells during a finale in order to increase the shell count without adding additional mortars or e-matches.

In order to align all eight shells and allow them to be easily rotated while stringing them together, the Maltese Shell Roller is a must-have tool. The shell roller is shown clamped to a table in Figure 28, with all eight shells aligned end to end. The shells are positioned so that all of the time fuse holes align in a straight line. You should be able to intersect all the time fuse holes with a straight line when they are positioned correctly.

Since all the shells must be able to rotate as a single group while spiking them together, it is necessary to glue them end to end with hot glue. Apply a liberal amount of hot glue to the center of one shell and then press it together with the next one in line while keeping the fuse holes properly aligned. Normally this step would not be necessary with a traditional multi-break shell, since the spolettes would help keep them together. Because these shells don't have spolettes, they are a little more difficult to work with and the shell itself is more prone to breaking in half during lift. However, the actual performance of the shell is not affected even when it breaks into one or more pieces, so we are not overly concerned with preventing that type of failure.

The shells are held together with a single set of eight or nine strands of strong twine. The twine being used here is the Imported 7 strand linen flax twine from PyroSupplies. You can also use double strands or more verticals if you don't feel your twine is strong enough or if you are overly concerned about the shell breaking into pieces during lift. Keep in mind though that the more verticals you use, the harder it is going to be to ram the newspaper into the gaps between each shell.

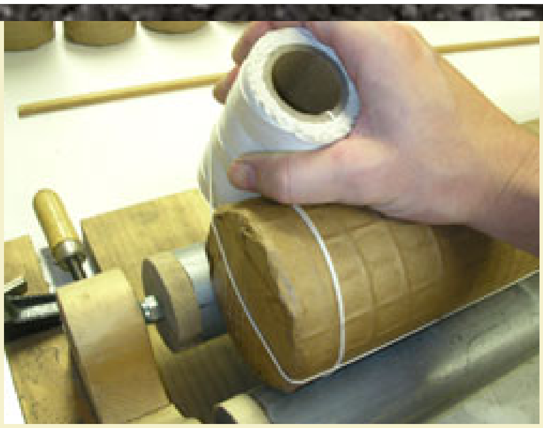

Figure 30: Leveraging the twine spool against the shell to cinch the twine tight.

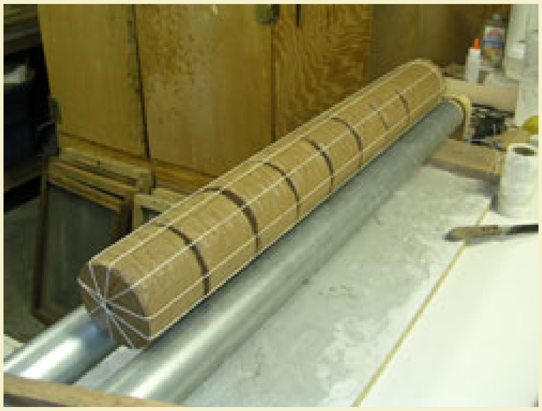

Figure 31: Completed vertical spiking for holding the breaks together.

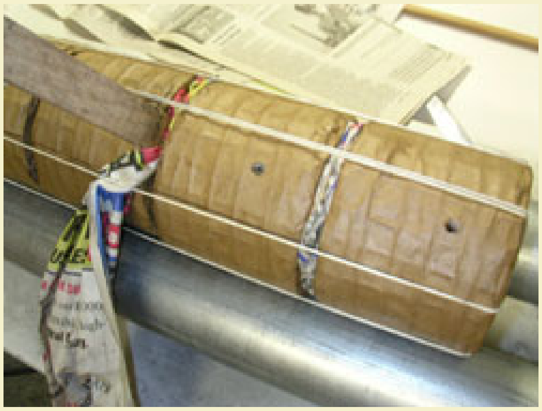

Figure 32: Ramming damply pasted newspaper between the breaks.

Again, since there are not spolettes for tie-off points, the twine must be started by tying it around the shell at one end, as seen in Figure 30. It is important to pull the twine as tightly as possible when spiking the shells together. One technique for cinching the string tight is to hold the roll of twine against the shell when cornering the ends and then torque it tight as seen in Figure 30.

Once eight verticals have been secured, you will make a ninth pass back down to the end of the shell where you initially tied off the twine. It is a bit tricky to tie off the twine at this point without letting some slack creep in. I find it easiest to work the twine under the horizontal tie-off wrap and secure it with a few half hitch knots.

Figure 31 shows the shells after they have been spiked together. You may notice that once the first shell in the group bursts, all the twine would then be unsecured and loose. You would think that the remainder of the unspent breaks would then break apart, but this does not tend to happen. The paper that is pasted over the twine tends to effectively keep the tension on the twine, as does the horizontal windings that are wound around the joints to take up the slack in the vertical wraps. Thus it is more efficient and just as effective to spike multi-breaks as a single group when building smaller diameter shells such as this, rather than spiking the breaks successively as each one is added. I use this same technique on four break six inch shells and have yet to have one come apart.

Next is the task of filling in the voids between each break with newspaper. This is an important step in preventing the shell from being able to flex during handling and from breaking in pieces when fired. The newspaper is lightly coated with wheat paste prior to ramming it in place with a thin wedge shaped stick, as seen in Figure 32. The paste helps the paper to ram in more densely and also solidify upon drying so that the paper is less apt to compress and allow the shell to bend. I use one page of typical news print to produce crumpled up pieces that are dampened by coating you hand with paste and then brushing it onto the paper by pulling down the length of it. It will take about two pages to fill each void, depending on how much of a gap you have. The paper must be worked under the spiking twine as you rotate the shell, ramming as you go.

The last step in assembling the breaks together is to tightly wrap several turns of cotton twine around the joints in order to cinch the vertical twine as tight as possible. In a normal multi-break shell this step would also add an additional fire block to prevent lift gas from getting between the breaks and setting the shell off out of sequence. For our piled shell this type of failure can not occur.

The cotton twine is applied in bands of four strands, which feed off of four separate spools. I find that the most useful tool for doing this is to make PVC spools of twine and then slip them onto the rotating jig for winding black-match twine that is described here. This jig will rotate as you pull from the four spools at once, which allows it to auto-position itself for minimal binding The jig is placed on the floor and the four strands are passed through a sheet of newspaper as seen in Figure 34. You can then step on the paper with one foot to control the resistance of the twine as you roll it onto the shell. This setup allows you to really crank the twine onto the shell with a lot of

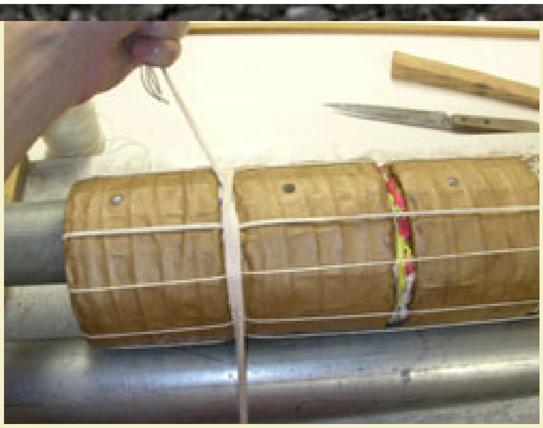

Figure 33: Starting the horizontal twine wraps with a clove hitch around the last break.

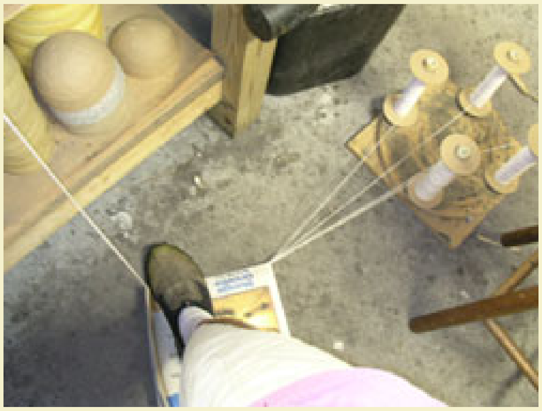

Figure 34: The spool arrangement with foot pressure for tension.

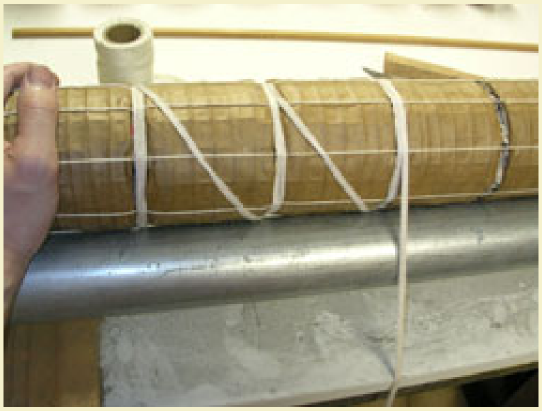

Figure 35: Tightly wrapping many turns of twine around the joint gaps.

tension, giving you a very solidly spiked shell that bends very little even before the paste wrap is applied.

The twine is started with a clove hitch around the first junction at one end of the shell, then progressed from one junction to the next. Use as many turns as it takes to build the twine up almost flush with the outside of the shell casing. If you didn't ram enough newspaper, this can sometimes result in a lot of twine being used between breaks. Figure 35 shows how the twine is moved from one junction to the next. After the last junction is stringed, finish with another clove hitch the same way you started.

Pasting

This shell is pasted in with two turns of 60lb recycled kraft. The only purpose of this paste layer is to protect the string from the lift fire and help hold the breaks together. This weak grade of kraft does not add any integrity to the break strength of the casing.

A single sheet of kraft is laid out and pasted on both sides, but is not broken in the way you normally would when making canister shells. The paste is just smeared on by hand and then the shell is rolled up, as seen in Figure 36. Because this shell is so long, it can be difficult to roll the pasted paper on as tight as it needs to be. You should be able to see the string pattern through the paper after each turn, squeezing it down with your hands as you roll to insure a tight fit on the shell.

The ends of the shell are pasted over by tearing the overhanging paper into tabs as seen in Figure 37. The tabs are then folded down over the end and smoothed out. The shell should be stood on its end while it dries, preferably with air blowing across it in order to speed up the drying time.

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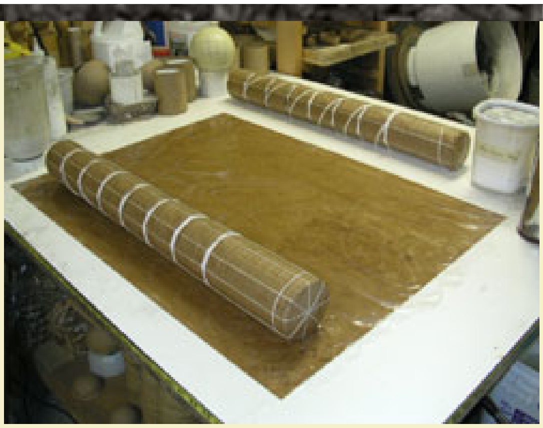
Figure 36: Finished shell being pasted in.

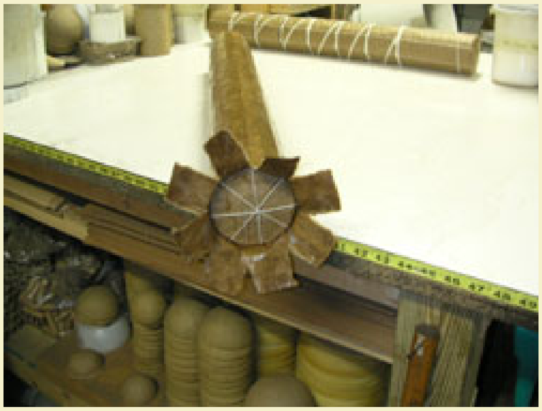
Figure 37: Pasting over the ends of the shell.

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4" Eight Break Piled Shell...

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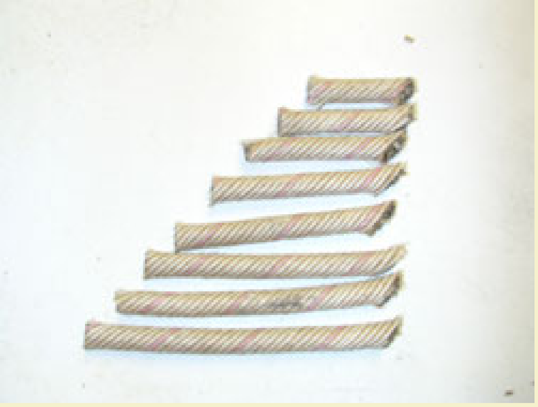
Figure 38: Increasing series of time fuses cut for each break.

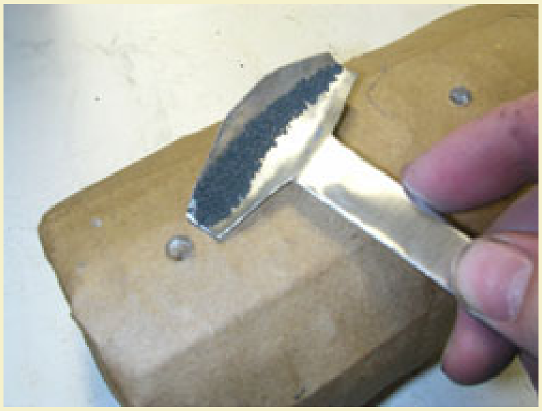
Figure 39: Charging the pipette with 2Fg black powder.

Fusing

Now for something a little different. Normally you would be lifting and leadering your shell at this point, but you haven't even fused it yet! The first thing you need to do after the paste wrap completely dries is to locate all the fuse holes and open them back up. This can be a little tricky, since the paper is thicker this time and you don't have any markers to look for. What you have to do is poke around very lightly with an awl or other sharp object until you find one of the holes. Once you find one hole, it is easy to find the rest because they are all in a straight line (or at least they should be). Care must be taken when searching with the awl though, since the shell casing is actually quite thin and if you punch a hole through it you will create a breach in the casing that will cause it to burst when the shell lifts. When the awl hits the hole, it will go through very easily. If you meet any pressure at all, move on to another spot.

Next you need to cut eight pieces of time fuse that correspond to the break timing that you want. These will look something like Figure 38, with an increasingly longer piece of fuse for each break. Of course you can do anything you want, you have a lot of control over timing with this method. If you wanted to have two shells going off at the same time for each break, you could cut four sets of fuse pairs. You can cut fuses that have only a very slight increase in length in order to have a very rapid series of breaks. You are somewhat limited if you want delays longer than a half second when using standard Chinese time fuse, however. For example, if you wanted a second between each break, which means you would really have to send this shell up high for it to complete before hitting the ground, then your last time fuse would need to burn for at least nine seconds. But since the diameter of the shell is only 3.5" minus 3/4" for the comet at the other side, you would not have the space to contain the 4" segment of time fuse required to burn for 9 seconds. Only about 1/4" of the time fuse can protrude outside the casing due to space constraints, so the longest fuse you could use is about 3" long.

If you were fuse the shell with home-made spolettes, then you could ram them with a slower burning powder and get around this timing limitation. When using the spolette method you could simply charge the pipette that you glued to the inside of the shell and skip the hole time fuse insertion step. All you would need to do is open up the holes and fuse them with some black match leading to the outside of the shell. You could even ram the spolettes with a silver gerb composition and get a very interesting rising effect!

The time fuses cut for this shell start at 1-1/4" long and go to 3" long in 1/4" increments. Thus the eight fuses measure 1.25, 1.5, 1.75, 2, 2.25, 2.5, 2.75 and 3". This gives about a half second delay between

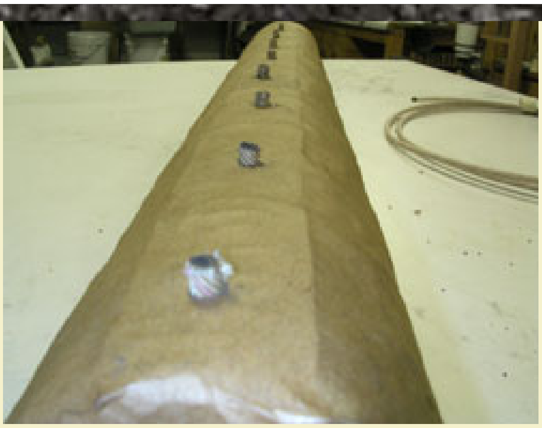
Figure 40: Fuses inserted into the pipettes.

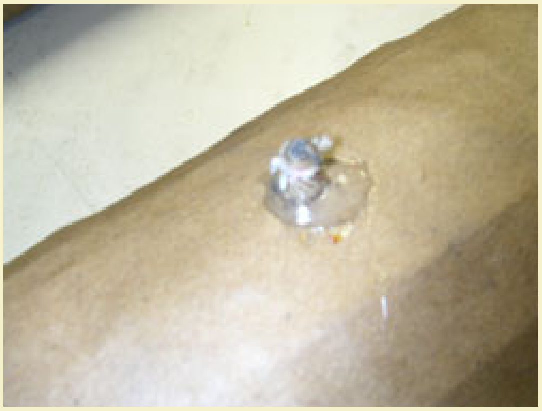
Figure 41: Hot glue sealing the base of the time fuse.

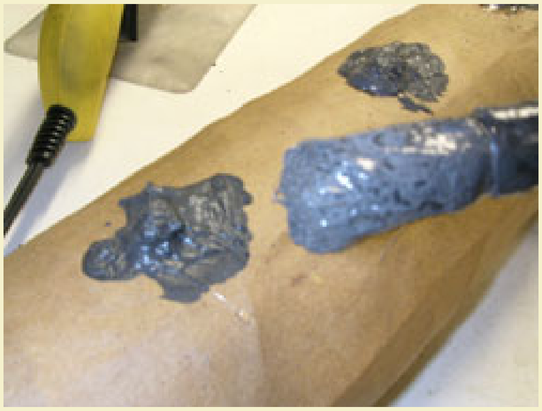
Figure 42: Priming the time fuse.

breaks, with the first break firing at around two seconds. Note that one end of the time fuses is cut at a 45 degree angle, which is the end that is inserted into the shell. Since you can not cross-match the inside end of the fuse, it is cut at an angle in order to expose a greater surface area of the powder core.

Before each time fuse is inserted into its corresponding hole, a small amount of fine grain black powder is charged into the hole first as seen in Figure 39. This helps insure that there is something that takes fire easily in contact with the end of the time fuse, which will also create a strong burst of fire out the end of the pipette. You want to have a burst of fire out the end of the pipette instead of the little poof of sparks you get at the end of a time fuse when it burns through. Note that this method of fusing, a central pipe filled with a small BP charge into which a tight fitting piece of time fuse is inserted after the shell is completed, is the standard practice for fusing most Chinese shells. As long as you cap your pipettes with a tissue barrier so that the powder grains will always be contained right at the tip of the time fuse, then this method is just as reliable as cross matching the time fuse, and actually gives better fire transfer than cross matching.

Figure 40 shows all eight fuses in place, with only 1/4" or less of the fuse sticking above the shell wall. The last couple of fuses will actually be longer than the internal pipette, so they will break through the paper barrier and thus do not require the BP charge. They will be in contact with the burst charge however, so ignition should not be an issue.

Next you need to apply hot glue around the base of each time fuse, which is important for preventing the lift gas from leaking in around the time fuse and setting the breaks off in the gun. Make certain that this glue bead is complete and that there are no air gaps.

The time fuse ends are now heavily primed by first making a slight cut into the end of the fuse with a razor to expose more of the powder core, then applying a thick prime slurry on top as seen in Figure 42. The heavy prime insures that all the fuses will take fire from either the passfire running down the side of the shell or, failing that, from the lift charge when the shell fires. Once the prime slurry is applied, the additional step of dusting the wet prime with a fine grain black powder or some corning dust will add an even greater degree of ignitability. Figure 43 shows to completed shells with primed and dusted fuses in place.

Lifting
This shell is lifted using the Maltese method, which is described here. The charge used is 150g of 1/8" rough powder, but could vary depending on how strong your home-made meal is. I use home-made spruce charcoal and ball-mill my meal to a very fine state before making the rough powder, so the lift is quite strong.

Careful observation will reveal that the lift charge has actually been attached to what would normally be considered the top of the shell, which is the first break. The break with the bottom shot, which is the last one to fire in the sequence, has been located at the top of the shell. This upside down arrangement is a safety precaution that is

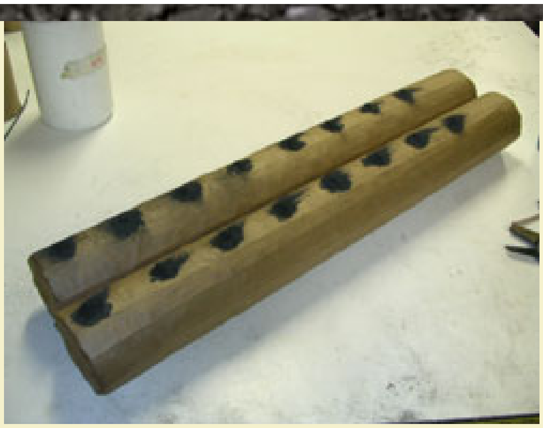

Figure 43: Primed and dusted fuse tips on two shells.

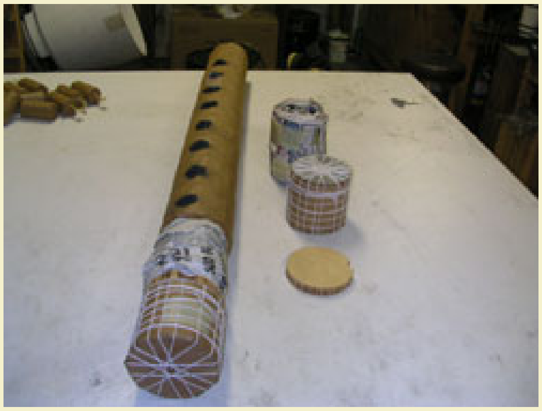

Figure 44: Assembling the lift components.

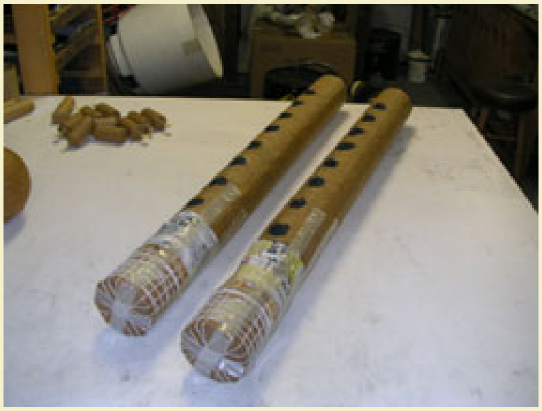

Figure 45: Lift components held in place with fiber tape.

done to keep the bottom shot in the least stressful and least destructive location. Since the bottom shot will destroy the mortar and generate dangerous steel shrapnel if it flower pots, the worst location for it would be right above the lift charge. With normal multi-break construction this is unavoidable, but with the side fused shell it can be fired from either end. By putting the bottom shot on top of the shell, it will be far less likely to ever experience a gas leak or side rupture, and in the event that the bottom shot did go off before the shell lifted, such as in the case of a passfire failure, then the flash detonation would occur safely outside the mortar (assuming your shell sticks out the top of the mortar, which it should.)

Two wads of rolled newspaper are used for the sabot, allowing for more cushioning against the lift forces. The passfire entry hole in the lift charge can is positioned slightly to one side of the chain of time fuses, as seen in Figure 44. The passfire tube will run right down along the side of the primed fuse tips. I used a paper punch to punch a small hole through the leader pipe right next to each time fuse. This may not be necessary however and could reduce the propagation speed of the piped match by causing a loss of the internal pressure. It is likely that the primed fuses would all take fire even without the holes punched in the side of the leader.

Figure 46 shows one large piece of 30lb kraft paper being used to roll three turns of paper around the shell. Unlike normal multi-breaks, the side fused method requires the whole shell to be covered in paper so that the primed fuses are protected from sparks. The paper also helps contain the gases when the fuse prime ignites, which helps propagate the fire between the primed spots and insures complete ignition.

The paper is tied around the top of the shell using two separate tie points, as seen in Figure 47. Only a minimal amount of fuse leader is required, since the shell will likely be sticking out from the mortar when it is loaded.

This shell can be fired from a standard size 4" steel mortar and still lift to a proper height. In fact, this shell is designed to be fired from a standard 4" mortar. If an overly long mortar is used that allows the entire shell to fit inside with nothing sticking out the top, then your risk of flower potting will greatly increase. Don't be afraid to have a couple feet of shell sticking out above the top of the mortar, it is actually less stressful for your shell to be fired this way. If you must use a long mortar, you should reduce the amount of lift charge accordingly. The longer the mortar, the less lift you need. Of course many times you don't know in advance how long a mortar will be when firing shells such as this at competitions, so it is best to design for a standard size 4" mortar and not worry about it. Otherwise it is advised that you test your shell from your own custom mortar and then bring that mortar with you to competition in order to eliminate this very important variable.

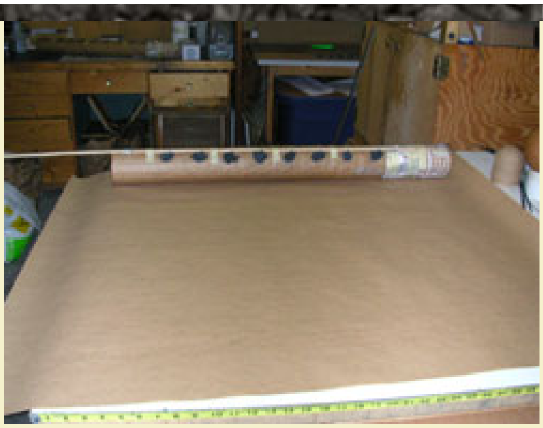

Figure 46: Rolling the outer wrap around the shell.

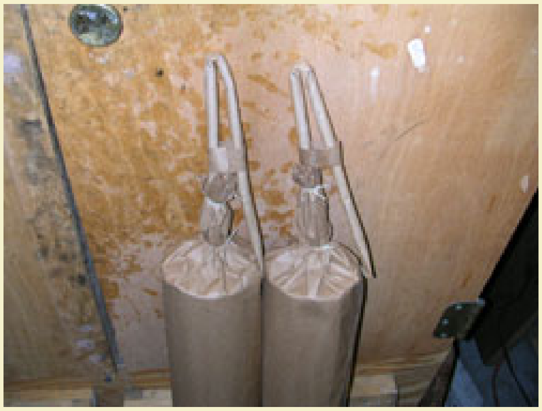

Figure 47: Finished shells ready to fire!

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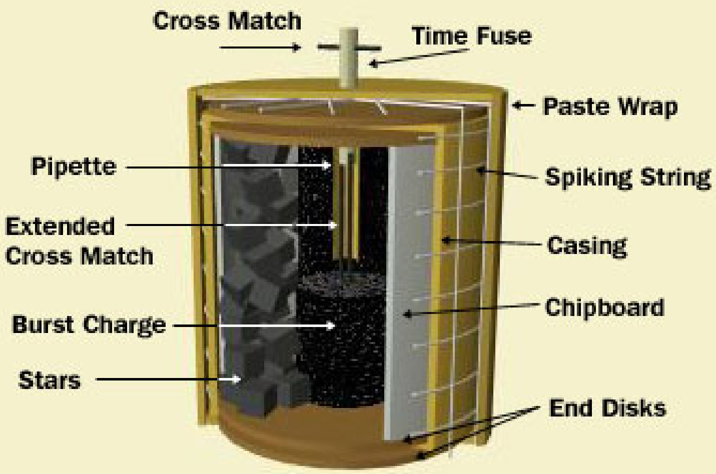
Build This...

4" Color Break Canister Shell



December, 2001 Issue

Build This:
Learn the basics of canister shell construction.

Tool Tip:
Build a Spiking Horse.

Technique:
Shell spiking basics.

Class 'C' Corner:
New Red Glitter Effect!

Materials:
(2) 6-3/4" x 24" strips of 70lb virgin kraft, grain short (case)
(1) 3-1/2" x 22" chipboard, grain short (liner)
(2) 7-3/4" x 24" strips of 70lb virgin kraft, grain short (paste wrap)
(1) 11" x 24" strip of 30lb kraft, grain short (outer wrap)
(1) 5" x 8" sheet of tissue paper (burst wrap)
(4) 3-1/2" kraft or chipboard end disks, 1/8" thick
(1) 1-3/4" piece of time fuse
(1) 3/8" ID x 1-3/4" long pipette (2-3 turns of 70lb kraft)
(1) 3-3/4" of 4 strand cross match
(1) 1" piece of 4 strand cross match
(1) 15" piece of 8 strand black match
(1) 30" quickmatch leader
(1) 1.5 oz (42g) 2FA lift charge

3/8" stars, flax twine, 2FA black powder, white glue or wood glue, masking tape

Tools:
Rubber mallet, 3-1/2" Dia case former, 1-1/4" OD dowel or pipe, cross match punch, hot glue gun, 7/32" drill bit, scissors, anvil cutters.

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Build This...

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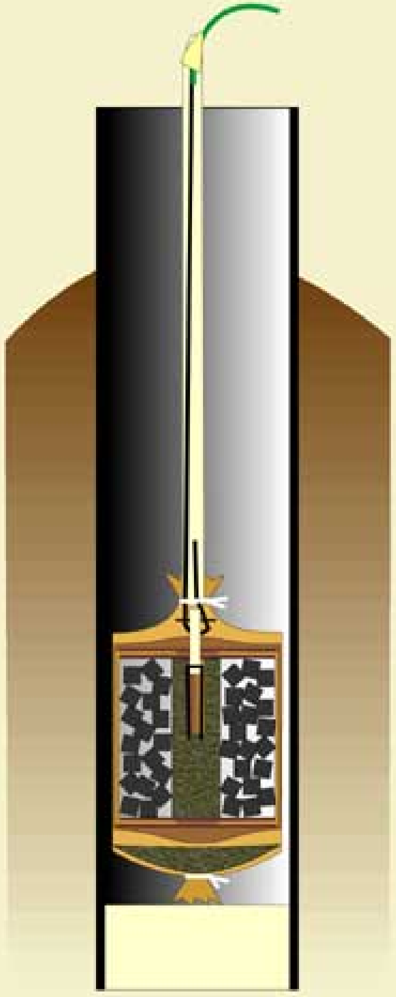
4" Color Break Canister Shell



Introduction:

This article describes one method for constructing a four inch canister shell, which is a good starting point for anyone new to canister shell construction. The method presented here is very similar to the traditional Italian methods as presented in Traditional Cylinder Shell Construction by A. Fulcanelli in Pyrotechnica IX. There are perhaps as many variations for making canister shells as there are people making them, but many key construction principles are common between them.

The canister shell has several advantages and disadvantages when compared to the spherical style shells developed in Asia. The canister shape is such that it maximizes the volume of display material that can be carried for a given diameter. This cylindrical shape is ideal for holding smaller cylindrical inserts such as whistles, serpents, salutes and even smaller shells. The flat ends of this type of shell also make it possible to stack them on top of each other to form longer shells containing multiple breaks, something that can not be easily done with spherical shells.

Spherical shells, however, are naturally stronger and ideally suited for symmetrically round breaks. While a round shell is constructed simply using pasted paper, the canister shell involves a more complex arrangement of paper, thick chipboard disks and a tight wrapping of twine.

The flat bottom of a canister shell must be able to withstand the immense pressure applied against it when fired from a mortar. Since there is less blow-by of lift gasses around a canister shell when leaving the mortar compared with a round shell, the pressure on the shell bottom is even greater. Due to this increased stress during lifting, canister shells must have as much structural integrity as possible. The shell contents must be packed tightly with no voids. Failure to produce a solidly filled canister can result in the shell compressing from the force of the lift and the weight of the shell, causing the sides to split open and spew the burning contents out of the mortar like a mine instead of a shell (a failure known as a "flowerpot").

The casing of the shell must be air-tight so that hot gasses do not enter into the casing during lift, also causing it to flowerpot. The gases generated from burning black powder are just as capable as any spark when it comes to igniting surrounding material. These gases can leak in through cracks around inadequately pasted edges or around the entry point of the time fuse. The time fuse is usually located on top of the shell to keep it out of the high pressure zone and reduce the risk of it blowing through and causing a flowerpot. Bottom fusing canister shells (placing the time fuse on the lift side of the shell and allowing the lift to light it), while quicker from an assembly standpoint, is not recommended for shells over three inches diameter.

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4" Color Break Canister Shell...

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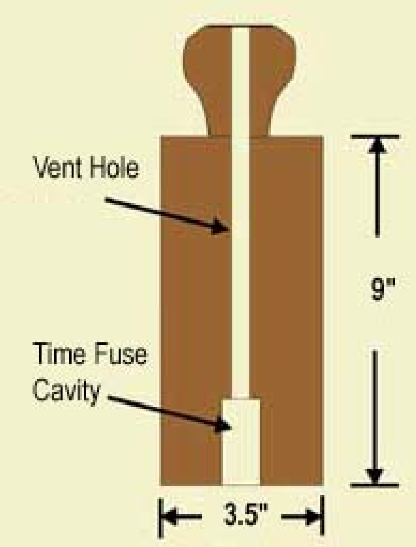


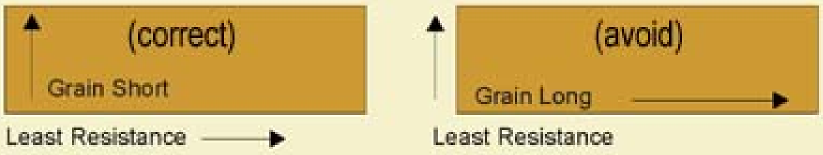
Figure 1: Typical case former.

Forming the Case:
The first tool you will need to obtain for making a canister shell is a cylindrical case former that is 1/2 inch smaller in diameter than the mortar diameter the shell is to be fired from. In this case, you will need a former that is 3-1/2 inches diameter and about 9 inches long, as shown in Figure 1. The case former depicted here was turned on a wood lathe from maple, then a center hole of 1/2 inch diameter was bored all the way through the former. The purpose of this hole is to prevent a vacuum from forming when the case is removed from the former. The vent hole was enlarged to 3/4 inch for a distance of about 2 inches into the bottom of the former to easily accommodate a piped time fuse or spolette. The optional handle was turned such that there is a large flat surface on top, which helps balance the former when resting on its handle during the end disk pleating process.

Getting a suitable former is often the first obstacle faced by new shell builders, and there are many creative options other than having one turned on a lathe. For instance, a segment of HDPE mortar pipe used for 3 inch shells can be used as the case former. The only disadvantage to this is the lack of a solid end for pleating over the end disk, but this shell size is small enough that you can get away with it.

If you do not have 3 inch HDPE laying around, you can also take a segment of 3 inch PVC and build it up to the proper diameter by rolling paper around it. When enough paper is rolled to bring the O.D. up to 3-1/2 inches, a single turn of clear packing tape can be wrapped around it to provide a smooth surface so the case will slide off easily. One could even try and center a smaller PVC pipe inside and fill around it with plaster of paris or some type of masonry patching compound in order to produce a solid end to the former. The diameter of the center hole needs only be large enough to accept the largest diameter time fuse or spolette you ever plan to use, with extra room allowed for ease of insertion.

Once you have your former, you are ready to start rolling cases. Prepare two strips of 70 lb kraft paper that measure 6-3/4" x 24" long, with the grain running parallel to the shorter distance (grain short). All the paper strips used in building this shell will be grain short, which not only allows the paper to roll easier in the case of chipboard, but also provides a greater resistance to buckling when forces are applied against the ends of the shell, such as during lift. The grain of paper is usually not easily visible, but can be determined by folding or rolling the paper parallel to both the length and width of the strip. The direction that folds or rolls easier is perpendicular to the direction that the grain is running. If you are trying to roll chipboard and it starts to wrinkle or creases appear, then you are rolling against the grain. Grain can be harder to detect as the paper gets thinner, but should still be easy to find with 70 lb. kraft.



The reader must be aware that there are many kinds of kraft paper on the market, and while many of them can be made to work with canister shells, the ideal grade is known as virgin kraft. Virgin kraft can be identified by a lighter tan color with very few speckles of tell-tale recycling evidence. The true test, however, is to get a piece wet and observe how it resists tearing. A good piece of virgin kraft should be able to be soaked and crumpled into a ball, then flattened back out without falling apart. The desire for this characteristic becomes apparent during the pasting process. Virgin kraft is most often sold in sheets rather than rolls, but can occasionally be found in rolls too.

Having cut your two strips grain short, proceed to roll them around the case former while using a piece of masking tape to hold the last turn down. When multiple strips are used to form the case, such as in this example, simply interleave the next strip slightly with the one before it and continue rolling. The general rule is one turn of paper for each inch of shell diameter, thus this case will have about 4 turns of paper. The case should be able to slip off the former when complete. If the case tends to get stuck, try rolling it with a few inches overhanging the end it is to be removed from.

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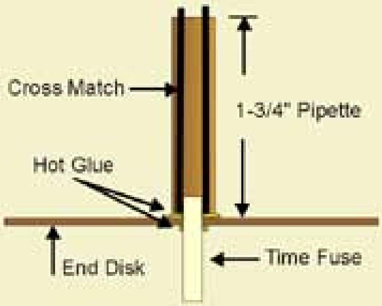

Figure 2: Time fuse assembly details.

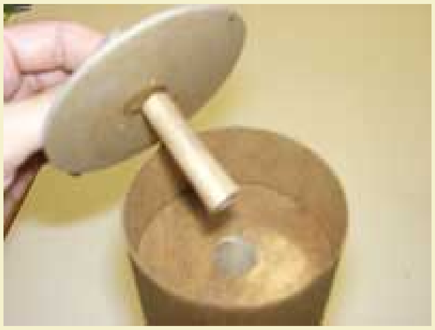

Figure 3: Inserting the fused end disk.

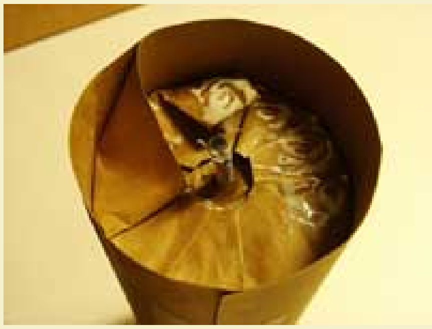

Figure 4: Pleating over the end disk.

Fusing the End Disk:
After the case has been rolled, an end disk containing the time fuse is placed on the end of the former with the edges of the rolled case extending beyond the former as shown in Figure 3. The paper should overhang such that it comes fairly close to the time fuse when folded over, but does not hit the time fuse or its surrounding glue.

To prepare the end disk and time fuse as shown in Figure 2, first drill a 7/32 inch diameter hole in the center of a chipboard disk. The disk should be the same diameter as the former, 1/8 inch thick and made of either chipboard or kraft. The kraft disks are stronger, but either type will work here. Disks can be purchased with 1/4 inch holes already punched in them, but a snugger fit around the time fuse can be produced by drilling your own hole and making it slightly smaller than 1/4 inch. This helps reduce the chances of gas leaks or getting blown in if used for multi-break shells.

The time fuse used here is the chinese type which burns approximately 2.2 seconds per inch. A 1-3/4 inch piece will be center punched 1/4 inches from each end, so that the actual length of fuse used for the timing is 1-1/4 inches. This will give a delay time of almost 3 seconds for the shell to reach its break height. If you have Bicford or Japanese time fuse you would rather use, then use a stop watch to time a 10 inch segment of it and calculate its burn rate. The burn rate will then dictate the length of fuse required to give 3 seconds of delay.'s b

Mark a line 1/4 inch from each end of the time fuse, then use an awl to punch a hole through one of the marks. The hole will receive a piece of cross match that is about 3-3/4" long. This 4-strand black powder type fuse should be about 3/32" in diameter and coated both externally and internally with powder to achieve a reliable flame transfer to the piece of time fuse. The other hole can be punched now, or it can be punched after the shell has been pasted and dried. If it is punched now, a piece of masking tape should be pinched around the fuse prior to pasting the shell so that paste does not enter into the hole.

With the cross match centered through the time fuse, insert the time fuse into the hole previously drilled into the end disk. Adjust the time fuse so that the cross match is about 1/4 inch from touching the disk, leaving ample amount of time fuse protruding from the other side. Using a hot glue gun, apply a bead of glue around the base of the time fuse on the side not containing the cross match.

While the glue hardens, roll 2-3 turns of 70 lb kraft around a 3/8 inch rod to produce a thin walled tube that is 1-3/4 inches long. This "pipette" will be used to guide the cross match into the center of the shell so that the burst charge takes fire from the center point rather than at the top of the shell where the time fuse enters. The fire propagation will progress faster when propagating in two directions instead of one, helping to break the shell at the center point instead of from one end.

Fold the two ends of the extended cross match up and slip the pipette over them, sliding it down until it almost touches the end disk. Place another bead of hot glue around the base of the time fuse and sink the pipette into it before it dries. The resulting assembly should look like Figure 2.

Once the hot glue has dried and is stable, insert the fused disk onto the end of the rammer as shown in Figure 3. This method of shell construction is known as the "upside down" technique, since the shell will be loaded in the upside down orientation and closed with the bottom disk. An alternate method involves placing the bottom disk on first, then closing with the fused disk after the shell is loaded. This author finds it more difficult to insert the fuse assembly through the rough powder and burst charge of a tightly packed shell as compared to simply loading it upside down and finishing with a plain disk.

The paper extending beyond the bottom of the disk must now be pleated over the disk using white glue as shown in Figure 4. Each layer of paper should be pleated individually, such that there are four layers of pleated paper stacked on top of each other. Once the last layer is pleated, a rubber mallet is used to tamp down the paper and get them as flat as possible.

At this point the case is slipped off the former and inverted for loading. A small block of 2x4 with a 1/2 inch hole bored through the center makes a good stand for the case while loading it.

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Loading the Shell:

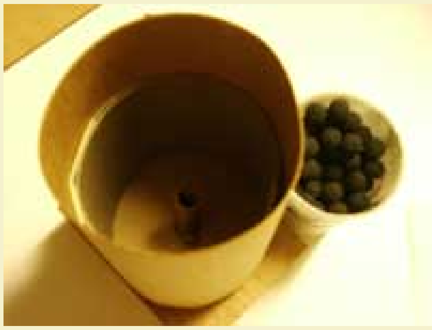

Figure 5: Chipboard liner in place.

Before the contents of the shell are loaded, a liner consisting of two turns of .01"-.02" caliper chipboard is inserted. The chipboard may be purchased in sheets from some print shops, or even salvaged from scrap cereal boxes. Poster board paper may also be used for the liner, although three turns may be required. The purpose of the liner is to provide a seating for the end disks and add further resistance to crushing forces upon firing the shell. The strip should be 3-1/2" by 22" long, grain short. Smaller strips may be taped together end-to-end if a 22" strip is not available. The chipboard is inserted by loosely rolling it up so that it may be dropped into the shell casing, then unrolled inside so that it compresses up against the walls as shown in Figure 5.

The next step is to load the desired stars chosen for the break. These may be either cut or round stars, with cut stars being the traditional type used. The size of the stars should range between 3/8" and 1/2" regardless of the type, with 3/8" probably the most common for this size shell. Larger pumped stars may be used when making stacked comet breaks, but that is a different type of shell than described here.

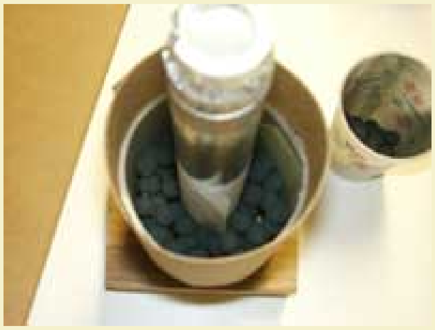

Figure 6: Filling stars around the canulle.

Before loading the stars, a special tube known as a canulle is inserted into the center of the case to prevent stars from filling the void where the break charge will reside. The diameter of the canulle dictates the amount of burst charge that will be used. For this shell the canulle will be 1-1/4" in diameter and about 9" long (the extra length is used for making longer insert shells and not really required here). The author made a canulle by wrapping paper around a piece of 1" PVC until the proper diameter was reached, then carefully covering the paper with aluminum foil tape. This tape is to reduce the friction when removing the canulle from its tissue paper sleeve (explained below).

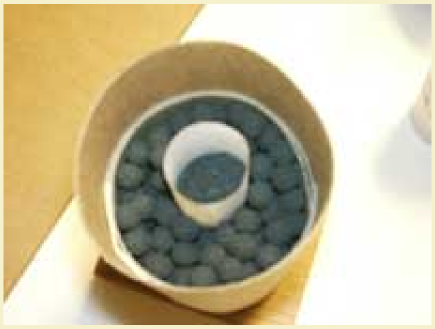

Figure 7: Stars and burst charge loaded.

Due to problems with the canulle getting stuck after loading the stars around it, as well as the burst charge migrating into the gaps between the stars, a tissue paper liner is used to contain the burst charge and ease the canulle removal process. This is achieved by wrapping the canulle in two turns of tissue paper with a slight overhang at the bottom. The overhanging tissue is crimped over the end of the canulle and inserted into the center of the case (time fuse must fit inside the canulle). The size of the tissue sheet used for the sleeve is about 5" by 8" long, resulting in a 5" long sleeve.

The stars are now poured in around the canulle while it is held in place. Figure 6 shows the foil covered canulle with part of the tissue wrapped visible above half a load of round stars. Loosely fill the stars to the top of the chipboard liner, then slowly remove the canulle from the tissue sleeve. The perfectly formed central cavity is now filled with 2FA black powder for the burst charge. Fill the cavity to the level of the chipboard liner as shown in

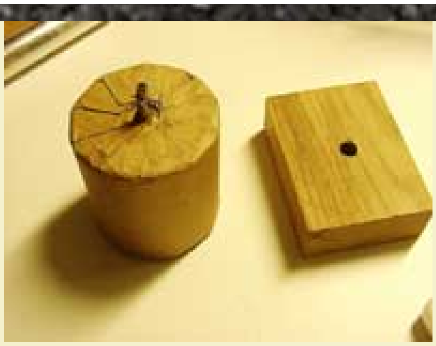

Figure 7, then crimp the remaining tissue down on top of it.

Figure 8: Shell ready for spiking.

With the burst charge loaded, the stars can now be consolidated by bouncing the casing up and down. If the shell contains chlorate stars, special care must be taken not to tamp or pound the stars, as painful accidents have occurred while tamping sensitive chlorate stars in the past. There is no need to whack the case with a stick or force the stars down with direct pressure. Simply bouncing the case should get the job done. As the stars settle, add more to fill the empty space.

Once the stars are compacted and nearly reaching the top of the chipboard liner, a rough powder known as polverone is used to fill the remaining cavity so that it is level with the top of the liner. This is simply a mix of mealpowder or green-mix with 5% dextrin that has been wetted and crudely granulated by pushing through a screen of 1/4" hardware cloth. When dry, it forms a gravel like material that is used to fill voids or top off the shell after loading the stars. The non-compressible nature of polverone, as well as the fact that it burns away with no falling debris created when the shell breaks, are the main reasons for its use.

Once the shell is solidly filled, the bottom disk is put into place and pleated in the same way the top disk was done. Since the rubber mallet can not be used to pound the paper flat this time, the bottom of the shells is pressed down against the table and rotated until it is sufficiently flattened.

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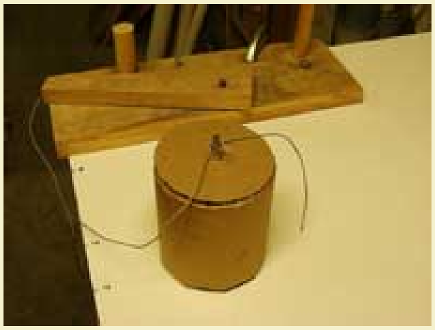

Figure 9: Flax twine tied off to time fuse.

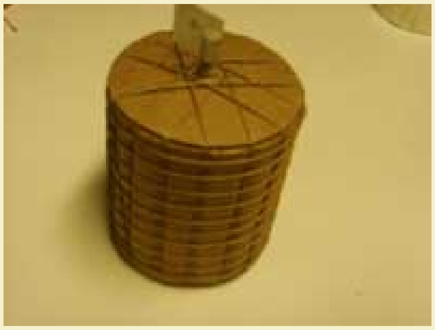

Figure 10: Spiking is completed.

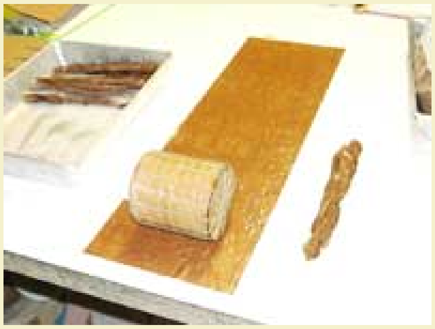

Figure 11: Pasting in the shell.

Spiking and Pasting:
Prepare the shell for the spiking process by applying another end disk to both ends of the shell using white glue to hold them in place. The internal end disk provides resistance to forces generated inside the shell, while the outer disks provide resistance to pressure applied external to the shell during lift. The paper sandwiched between them ties them in with the rest of the case, providing a very strong multi-ply end cap that will usually survive the shell burst in one piece. When building larger shells, it often becomes necessary to stack even more disks to increase the strength and avoid them getting blown in during lift.

The next step is to spike the shell with either cotton twine or a good flax twine. Flax twine is highly recommended over cotton twine due to the fact that it doesn't stretch the way cotton does when tensile stress is applied. However, the stretching resulting from the use of cotton twine can be greatly reduced by soaking it with paste prior to spiking. Paste can even be worked into the twine after it has already been spiked onto the shell prior to pasting it in. The difficulty in finding good flax twine, not to mention its steep price tag, often leaves the builder with no choice but to use the cotton twine.

For complete details of spiking theory and procedure, click this link to the spiking basics article. In addition to this article, the details for constructing a simple spiking horse can be found in this month's tool tip column. Following the directions provided in these resources should lead to the results shown in Figure 10.

With the shell tightly spiked, it is now ready for pasting. The type of paste used almost exclusively in fireworks manufacturing is made from the gluten of flour. This can be purchased as wheat paste, also known as wallpaper paste, or it can be manufactured in the kitchen by boiling a mixture of flour and water. Due to newer types of wallpaper paste, the wheat paste is becoming more difficult to find. The brand names such as Golden Harvest can also be quite a bit more expensive than using flour to make your own paste. The advantage to using wheat paste is that it can be quickly prepared in small quantities using a blender, whereas flour paste usually made in 2 quart batches. Both types of paste can not be stored and will spoil after a few days, so any amount not used goes to waste.

If you choose to make your own paste, the process is as follows: Mix one cup of flour, preferably wheat flour, into 3 cups of water using a blender. In a sauce pan, bring three cups of water to a boil, then slowly pour the mixture from the blender into the sauce pan while stirring. Continue stirring until the paste reaches a thick consistency, then remove from the heat and allow to cool. Over heating will produce thick globs of paste on the bottom of the sauce pan.

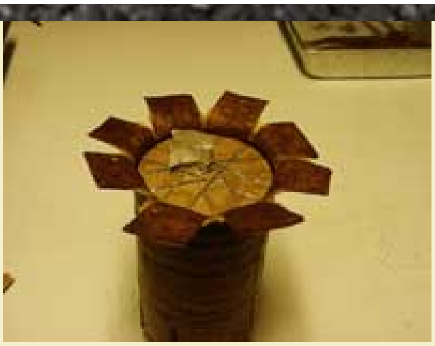
Figure 12: Pasting in over the end disks.

Mixing the paste using commercial wallpaper paste such as Golden Harvest is easiest to do by filling a blender half full of warm water, run it on high speed and slowly add the wheat paste until the paste is so thick that it no longer has a vortex in the center. The paste should be at least as thick as pancake batter, and you should be able to grab a handful of it without it running out of your hands.

Once the paste is prepared, it must be worked into the paper very thoroughly so that the paper fibers are completely saturated with paste. This process, known as "breaking" the paper, begins by coating each sheet of paper with paste on each side using the hands to smear it around. The paper is then folded like an accord ian in the long direction and crumpled with the hands to work in the paste. The long piece of crumpled, wet paper is then folded in the other direction and squeezed repeatedly. The resulting wad of saturated paper is then set aside and the process repeated for all other strips of paper required to paste the shell.

The general rule for number of paste layers for shells between three and six inches diameter is one layer per inch of diameter, thus there will be four turns of pasted paper for this shell. This results in two sheets of paper measuring 7-3/4" by 24" long, grain short. After each of these strips os broken in as explained above, they are laid flat and the shell is tightly rolled up in them. Prior to rolling the shell, some paste should be smeared all over the spiked string if the string was not previously pasted prior to spiking. The first turn of paper around the shell should be smoothed down so that it falls into the squares formed by the spiked string. The second strip is interleaved with the first and rolled the same way.

Care must be taken that the overhanging paper on each side of the shell is about equal in length. Once all the pasted strips are rolled onto the shell, the overhanging paper is ripped or cut into segments as shown in Figure 12. These strips are then pleated down similar to the way the casing was pleated onto the end disks. Some builders will simply fold all the layers over at once, but a cleaner and stronger paste job will result by folding them down one layer at a time. Any overlap at the bottom of the shell will result in a conical buildup of paper, which won't hurt the function of the shell but will increase the drying time. The strips should fold down around the base of the time fuse, building up around the base if necessary. The strips may also be ripped down the center slightly so that they can pass around the time fuse and lay flat. An alternate method is to pleat down the overhanging paper at the same time the shell is being rolled. This requires a little more skill, but can save some time when pasting many shells.

Once the pasting is complete, the shell should be dried as quickly as possible to prevent water from working its way into the inner casing. This can be done by putting the shell on a screen and placed out in the sun to dry. Using a fan to blow air across the shell will also speed up drying, and specially made dry boxes or drying rooms can be used that can completely dry the shell within a day or so. When the shell is fully dry, you should not be able to make an indentation in the paper with your fingernail.

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Volume 1, Issue 3

4" Color Break Canister Shell...

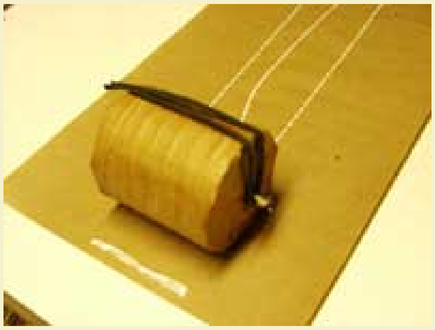

Figure 13: Rolling on the outer wrap.

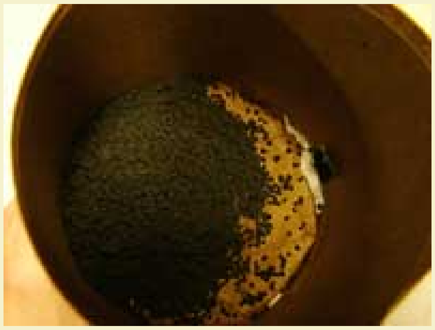

Figure 14: Loading the lift charge.

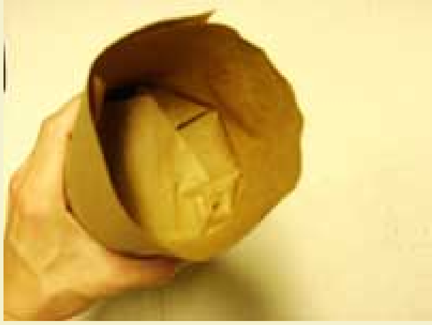

Figure 15: Folding in the bottom.

Lifting and Leadering:

Once the shell has been allowed to fully dry, two turns of 30lb kraft are rolled around the shell in order to hold the lift charge and secure the quickmatch leader. Since the leader will transfer fire to the top of the shell, a separate piece of fuse called the passfire must be used to get the fire to the lift charge. There are a few methods for creating the passfire, and the choice of which one to use depends largely on whether you are using commercial quick match or homemade piped black match, as well as the distance from the top to the bottom of the shell. For this article, a strand of raw black match is wrapped around the time fuse and brought down the side of the case to the bottom as shown in Figure 13. The outer wrapping will serve as the "quickmatch" pipe, which works fine for a shell of this size. For larger shells, some of which won't even have a continuous wrap of kraft from top to bottom, a paper pipe would be used to sheath the passfire match. Keeping the two strands of passfire match close together, apply a few lines of white glue down the length of the outer wrap as seen in Figure 13 and roll up the shell.

The shell is now inverted and ready for adding the 2FA black powder lift charge. The amount of lift charge is determined by the weight of the shell, and is generally calculated as one ounce per pound of shell weight. This will usually be about two ounces of lift for a single color break shell of this size.

Before the lift is added, a small wad of tissue paper is used to fill the air gap around the passfire match and thus prevent the lift charge from migrating up the side of the shell during handling. The tissue wad and lift charge can be seen in place in Figure 14. The glue line applied before rolling the outer wrap will prevent lift migration around the remaining perimeter of the shell.

After the lift charge has been added, the first turn of outer wrap is pleated in over the powder as shown in Figure 15. The second turn of paper is gathered up like a paper sack and tied off with a clove hitch knot. Pleating the first turn of paper is done in order to reduce the chances of any powder leaking from the bottom of the shell.

The shell is now ready for the final step of attaching the leader. This method was developed for use with homemade black match and hand rolled match pipe, thus a different method would be needed for using commercial quickmatch. A piece of 8 strand black match is passed through a 30" segment of leader pipe and a loop is formed at the end. This loop is passed around the base of the time fuse, underneath the crossmatch, and back up into the leader pipe for about six inches. If 4 strand black match is being used, then the loop would need to double back along the full length of the leader. The pipe is pulled down so as to cinch the loop around the base of the time fuse, then the black match protruding from the other end of the leader is cut flush with the pipe.

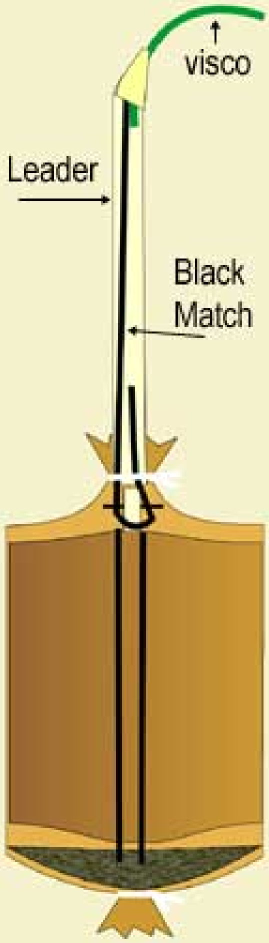

Figure 16: Details of shell leader.

The excess shell wrap is now gathered up around the leader and tied off with a clove hitch knot as shown in Figure 16. A four inch piece of visco safety fuse is inserted into the end of the leader and secured with a piece of masking tape wrapped tightly around the fuse and the leader. The use of visco is recommended over the traditional method of just extending the raw match several inches beyond the pipe, as raw match tends to burn too fast to allow the shooter to get far enough away from the shell when firing.

The long leader can now be folded over several times and secured with a band of paper for easy storage. It is also advised to roll a small tube, pinched off at one end, to use as a safety cap over the exposed piece of visco. This helps ensure against accidental ignition during handling at the firing line.

This concludes the basics of single break canister shell construction and provides the foundation for more advanced variations to be pursued once these techniques are mastered. Note that it is actually more difficult to obtain symmetrical breaks from smaller three and four inch shells than the larger sizes, and the hobbyist is encouraged to experiment with variations in break charge and spiking techniques in order to fine tune the performance of these shells.

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Volume 3, Issue 6

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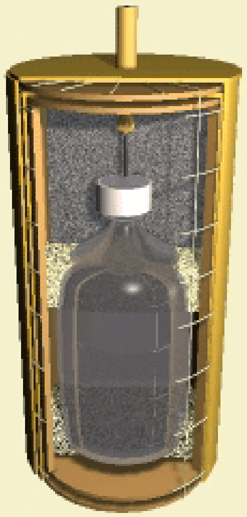
Build This...

4" Lampara Shell

by Liquid Gold



August, 2003 Issue

Letter from the Editor:
Current Events

Build This:
4" Lampara Shell

Design Notes:
Rolling Precision Stars

Tool Tip:
Build A Corning Machine

Class C Corner
Megatron, N. Praying Mantis

Summary:
The lampara shell is simply a salute charge atop a container of flammable liquid. The effect, in its most common form, is a rolling orange fireball with black smoke. This makes for an ideal daytime as well as nighttime effect. Colored, somewhat translucent fireballs such as red or green are possible, using methanol and various metallic salts as coloring agents. But that's for another installment; here we will concentrate on the most common form in the four inch size.

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4" Lampare Shell

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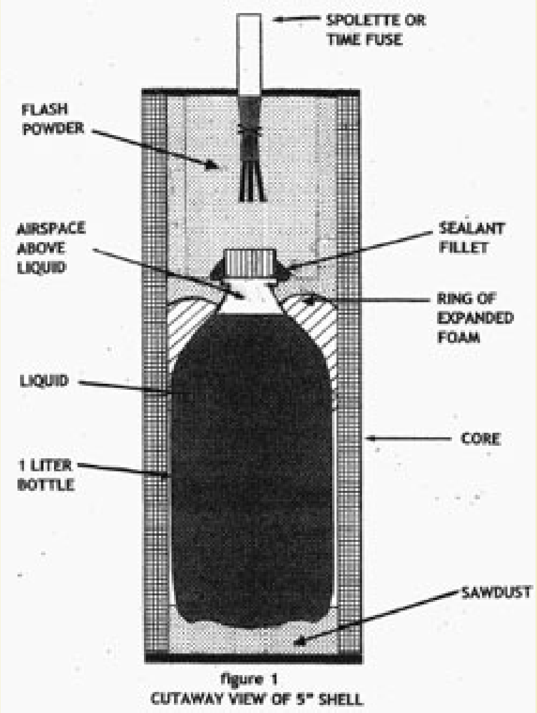

Figure 1: Lampara cross section.

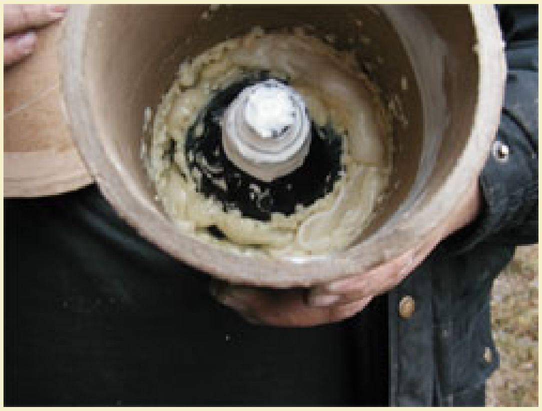

Figure 2: Foam seal around the 1 Liter bottle.

"Idle tubing is the pyro's playground"
- Kurt Medlin

My first encounter with the lampara effect was at the 1997 PGI convention in Amana, Iowa, where it was a signature effect in the display presented by Heartland Pyrotechnics Association. Having apprenticed under some of their master craftsmen, I began developing some techniques and methods to create a 4" lampara shell. The product of that development process is the successful design presented here as shown in the cross-section view in Figure 1.

A lampara shell is essentially a pyrotechnic form of a fuel air explosive in which a container of flammable liquid is ignited by a salute charge. The resultant effect is a 'heavy report' and a rolling orange fireball surrounded by clouds of thick black smoke. The combination of sound from the flash powder salute and the vibrant color patterns created by the combustion of the petroleum based fuel makes the lampara shell an ideal effect for both day and nighttime displays.

Although the word 'lampare' is generally used to describe shells of this nature, the term lampara is more technically correct; lampare is the plural form (Swisher, 1999.)

Related effects are the "Fire Flower Lampara," a chrysanthemum style shell with a lampara pistil (as displayed by James Denny and Patti Roman of the Michigan Pyrotechnics Arts Guild) and naphthalene based lampare.

BEFORE ATTEMPTING LAMPARA CONSTRUCTION ONE SHOULD POSSESS A THOROUGH UNDERSTANDING AND EXPERIENCE WITH CANISTER SHELL CONSTRUCTION. RESEARCH AND UNDERSTAND THE SAFETY ASPECTS AND MANIPULATIONS OF FLASH POWDER. WORK SAFE!

Materials Needed:

Case

For a 4" lampara shell, a 3.5" OD spiral wound tube with a minimum wall thickness of 1/8" to 5/32" will be the case. It provides the strength and integrity necessary to stabilize the container of flammable liquid during transport and from the force and pressure of the lift charge. The exact length of the tube required will depend on the height of the container and the amount of flash powder in the salute charge. In this example, the tube is 12" long.

Paper tubes that have been used for plastic shrink-wrap are an excellent 'free' source of casing material though they are also commercially available from pyro community suppliers such as Platte River Fireworks.

Cardboard End Disks

Two sets of 1/4" end disks will be needed for a 4" lampara. One set of 1/4" end disks will be used for the spolette/time fuse assembly and a second 'double set' of end disks will be sealed to one end of the tube that will become the bottom of the case. Depending on the exact OD of the tubes that you use for a case, your stock 3.5" end disks may be slightly over- or under-sized. Be sure there is sufficient wall thickness for the end disk to bond to. Resinous wood glues, such as Tite Bond Premium, give superior strength and moisture resistance over Elmer's or similar glues that would normally be used in standard canister shell construction.

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4" Lampare Shell

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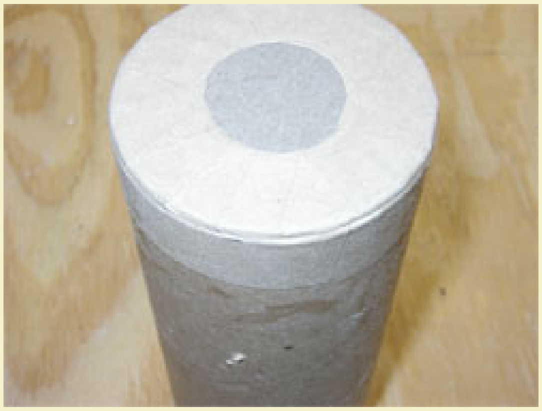

Figure 3: Pleated paper over bottom of the can.

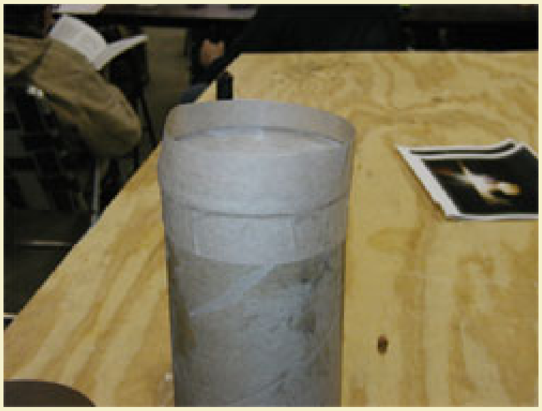

Figure 4: Piston made with wadding between two solid disks.

Container (bottle)

The ideal container is a plastic bottle made of High Density Polyethylene (HDPE). HDPE will not degrade or dissolve from exposure to the various petroleum fuels that may be used to create the lampara effect. While 16 or 20 ounce soda/pop bottles work well, the most compact and suitable container for a 4" lampara is the 20 ounce Gatorade bottle. Its size and shape provides the highest volume in as compact a container as possible while still leaving room for the required sealants and the salute charge. The 24 ounce bottle of Pepsi Products is about the maximum size for a 4" lampara shell.

Note: Most brands of plastic soda/pop bottles are made of PETE (Polyethylene Terepthalate) plastic and can deteriorate from long term exposure to petroleum distillate fuels, particularly gasoline. If in doubt, test your bottle/fuel combination for at least 3 months for signs of discoloration, brittleness or softening of the plastic.

HDPE bottles are available in various sizes and shapes from container/packaging manufacturers and suppliers and from Pyrosupplies.com.

Expanding Insulating Foam

Expanding polyurethane insulating foam, such as Great Stuff (Figure 2), is used to secure the container within the case.

Flash Powder

The standard 70:30 flash powder mixture of KClO4/dark aluminum is all that's required for the salute charge. For a 4" lampara, 6 ounces of flash powder is a minimum amount, larger amounts to taste. Due to the different densities of dark pyro aluminums, the amount you squeeze in will vary.

Fuel

Standard diesel fuel creates a nice orange fireball with lots of black smoke. Undiluted kerosene is a close second although almost any flammable liquid will have some effect. White gas (Coleman fuel), fuel oil, and used motor oil are also good candidates. A 50:50 or 70:30 mixture of gasoline and diesel, Kerosene, or motor oil will thin the mixture and maximize its dispersal in the air thus optimizing its ignitability and enhancing the effect though there will be some minor differences in the duration of the fireball and the amount of smoke produced.

When filling the bottle with fuel, leave approximately one inch of space above the liquid to allow for expansion due to temperature changes. Any leak or seepage from an over-pressurized container

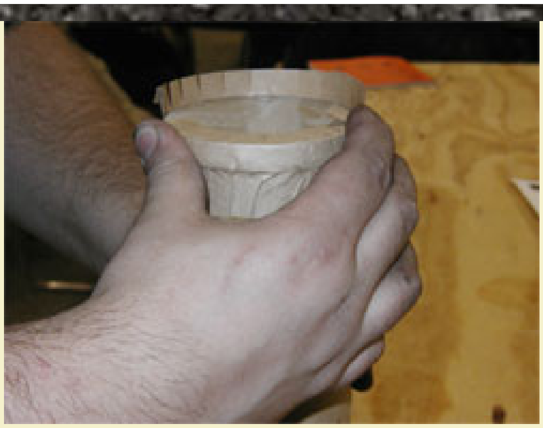
Figure 5: Loading the saetines.

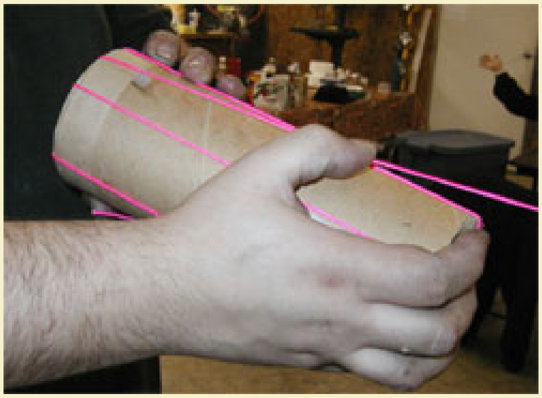
Figure 6: Horizontal spiking process.

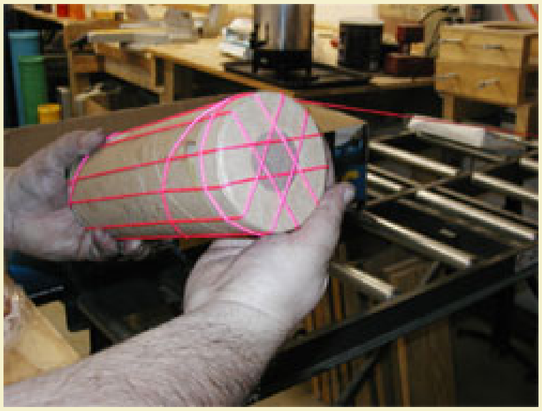
Figure 7: Masons twine used to illustrate pattern. Do not spike with this kind of twine!

could dampen the salute charge, dampen the spolette assembly or weaken the case and cause the shell to malfunction in the mortar and become a flaming ground bomb.

Colored fireballs in blue, red or green are also possible using methanol and various metallic salts as coloring agents.

Sawdust
Sawdust is used to fill in the space between the bottom disk and the irregular bottom of the bottle used. One inch of fill should be all that's necessary.

Sealant
A critical component of a lampara shell is the seal on the fuel container. It is essential that the sealant used be impervious to the fuel (or combinations of fuel) used. The leakage of even the smallest amount of fuel will likely have disastrous, not to mention embarrassing, consequences.

Permatex Form-A-Gasket No. 1 has proven to be a reliable sealant for this application. It adheres readily to HDPE, is easy to use, and is unaffected by petroleum fuels.

Solvent based urethane caulks are another practical option and have recently become more commonly available at home improvement stores.

Tests of latex caulk and RTV silicone adhesive for use as sealants were disappointing. Latex caulk was not fuel proof and did not provide a strong seal. RTV sealant is fuel proof, however, its major drawback is that when cured it readily peels from away from the smooth plastic cap (although this is not serious problem once the fuel container is secured in the case.)

Tape
1" - 1 1/2" wide gummed paper tape.

Time fuse/spolette

Although Japanese or Chinese time fuse could also be used, this design uses a spolette for the time delay. A 3-second time delay should be considered the minimum for a 4" lampara. To maximize the transfer of fire, use good quality stiff match and expose a good portion to the flash. With time fuse additional strands of blackmatch can be tied to the crossmatch. This may appear to be a bit of 'crossmatch overkill,' however, flash powders may sometimes be difficult to ignite; this is no place for shortcuts so it is vital to have plenty of blackmatch in direct contact with the salute charge. Whichever fuse option you choose for the delay, timing tests for a given length are crucial for safety and consistency.

Kurt Medlin's article on spolette construction (1999) is an excellent source of information on the art and craft of making hand rammed spolettes. Accompanied by numerous photographs, the article provides detailed step-by-step instructions that outline a practical method for making consistent and reliable spolettes.

A technical history of the Brock spolette is in Myke Stanbridge's article (1997).

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4" Lampare Shell

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Assembly:

Note: While relatively easy to construct, a lampara shell is not a "beginner" project. A lampara shell is as dangerous, if not more so, as any salute shell. The use of a flammable liquid in combination with flash powder significantly increases the potential for serious consequences. A thorough understanding of and experience with both canister shell construction and the safe use of flash powder should be considered as minimum requirements before beginning construction of a lampara shell. The Fulcanelli articles (1984, 1987) on traditional cylinder shell construction are a definitive source.

1. Prepare two sets of 1/4" end discs; one set of discs with a nosed spolette/time fuse assembly and a second set of doubled end disks that will be sealed to one end of a tube to form the case.

2. Fill the container with fuel to within 1" of the top of the bottle. Apply a thick bead of sealant to the threads inside the bottle cap and screw the cap onto the bottle. Apply enough sealant to completely cover the outside of cap where it connects to the neck of the bottle.

3. Seal the set of doubled end disks to one end of the tube with resinous wood glue.

4. Pour in enough sawdust to make a 1" layer in the bottom of the case.

5. Place the sealed, filled container in the case allowing the sawdust to fill any gaps between the bottom of the bottle and the end disc.

6. Apply a bead or two of expanding insulation foam around the upper third of the bottle as shown in Figure 2. Monitor this process closely - expanding foam may swell into the cavity for the salute charge or get underneath the bottle and lift it out of its seated position in the sawdust. While the foam is still tacky, trim back any excess that goes past the bottle cap. When cured, the foam will anchor the bottle in the case and form a sealed cavity for the salute charge.

Note: Butane is used as the propellant for expanding foam insulation products. The process of applying the bead(s) of expanding foam inside the case may create a pocket or concentration of highly flammable butane fumes. The application process should be done outdoors and away from any open flames or other ignition sources.

7. When the foam has cured (about 12 hours), fill the space above the bottle with the flash powder mix.

8. Glue the end disc with the nosed and crossmatched spolette/time fuse assembly in place with resinous wood glue.

9. When the glue has set, apply two turns of gummed paper tape, half of the width of the tape, to the areas where the end disks and case meet as in Figure 4. The excess is snipped, pleated, and glued to the end disk as in Figure 5.

10. Spike the shell with 16 vertical wraps of cotton or flax twine as shown in Figure 6. A partially spiked shell is shown in Figure 7. Note that fluorescent masons twine is used in Figures 6 and 7 for the purposes of making the twine more visible. Masons twine is a poor choice for spiking and is only used here for illustrations purposes.

11. The shell is pasted in with 4 turns of 70 # Kraft paper in two steps of two turns each. When the first layer is dry, the final two turns can be applied.

12. Dry the shell.

13. Lift and leader the shell with the fuse up. Use the general lift rule of one ounce of 2FA black powder per pound of shell weight. With experience you'll learn to control the altitude at which the shell breaks using shell weight vs. lift charge and timing to dial in a desired burst height.

Temperature extremes should be avoided in prolonged storage. The safest storage practice for competed lampara shells is to keep them in an upright position.

Such long and potentially heavy cylinder shells can generate greater lift pressures than standard single break shells. Avoid the practice of securing mortar plugs with wire staples, which often leaves the plug very vulnerable to the increased lift pressures of a lampara shell which can result in a blown plug. Plugs secured with nails or bolts installed across the grain of the wood plug are preferred as drywall screws may lack sufficient shear strength. For the lampara shell weighing 3 - 5 pounds, HDPE is the safest choice being sturdier than the traditional cardboard mortar. Your mortar should be well plugged (perhaps a double or even triple thick plug) and buried 75% of its length. Larger lampara shells weighing more than 6 pounds should be treated as a multibreak shell and shot from a steel mortar. The steel tube should be buried 100% of its length and the shell fired by e-match or a long length of visco safety fuse.

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Fulcanelli, A. 1987. "Traditional Cylinder Shell Construction, Part II." Pyrotechnica XI, pp. 4-48.

Medlin, K. 1999. "An Introduction to Making Hand-Rammed Spolettes." PGI Bulletin No. 117, pp. 23 - 37.

Stanbridge, M. 1997. "A Brief Technical History of Brock-Spoulette." PGI Bulletin No. 107, pp. 15 - 21.

Swisher, M. 1999. In "Mini Lampare" by 'Smokey.' PGI Bulletin No. 112, pp. 32 - 37.

Resources

Tom Backes
End disks, tubing for lampara casings
TJB@aol.com (563) 556-0219

Mike Korbylo, ATF Fireworks
quality HDPE mortars and firing systems
http://www.atf-us.com

PyroSupplies.com
HDPE containers
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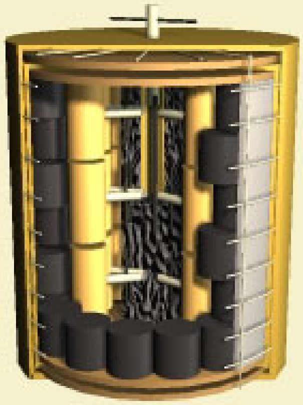
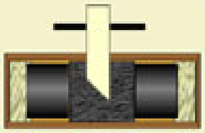
Volume 4, Issue 4

Build This...

5" Comet Shell with Scatter Stars





July, 2004 Issue

Build This:
5" Comet & Scatter Star Shell

Technique:
Using Star Plates

Technique:
Working With Paste

Tool Tip:
Home-made Star Plate

Class C Corner:
Angler's Ambition, ShowBiz

Summary:
This shell breaks with five rings of large comets, then surprise the viewer with an outbreak of asymmetrical scatter stars that dart in all directions. "They aren't go-getters, they aren't crossettes... what are those things?"

Prerequisite: 5" Comet Shell

Materials:

- (3) strips 24" long x (comet height x row count) + 3-3/4" wide 70lb virgin kraft, grain short (case)
- (1) 23" long x (comet height x row count)+1/4" wide chipboard, grain short (liner)
- (3) 24" long x (comet height x row count)+6" wide strips 70lb virgin kraft, grain short (paste wrap)
- (1) 36" long x (comet height x row count)+10-3/4" strip of 30lb kraft, grain short (outer wrap)
- (4) 4-1/2" kraft or chipboard end disks, 1/8" thick
- (1) 2" piece of time fuse (2.2 ft/sec)
- (1) 3/8" ID x 2-1/2" long pipette (2-3 turns of 70lb kraft)
- (1) 5-1/2"" of 4 strand cross match
- (1) 1" piece of 4 strand cross match
- (1) 17" piece of 8 strand black match
- (1) 30" quickmatch leader
- 70 3/4" dia x 7/8" long comets
- 60 3/8" pumped stars
- 30 1-1/2" long tubes, 7/16" I.D., 5/8" O.D.
- 30 1-1/8" long segment of time fuse

Tools:

- 4-1/2" dia. case former
- Rubber mallet
- 1-5/8" OD dowel or pipe
- Cross match punch
- 7/32" drill bit
- Hot glue gun
- 3/4" comet pump
- Brass hammer or 2 ton arbor press
- Scissors
- Anvil cutters

Unmeasured Materials:

flax twine, 2Fg black powder, 2FA black powder, white glue or wood glue, masking tape, wheat paste

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5" Comet & Scatter Star Shell...

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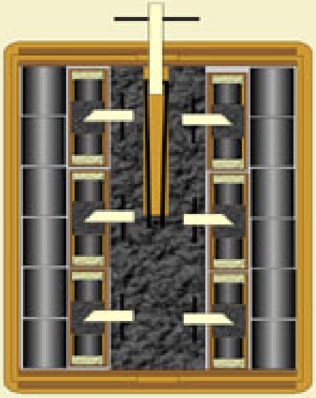

Figure 1: Arrangement of comets and scatter star inserts.

Introduction

Scatter stars are a unique type of insert shell that fires two stars in opposite directions. They are generally fired in clusters so that the cumulative effect is a dark break followed by a surprise of stars darting around with no symmetry or central point of origin. The use of scatter stars in this project is combined with a comet break canister shell, such that the viewer is first treated to a nice break of big comets, with a short delay before revealing the unexpected cluster of scatter stars darting in every direction. I used a three break version of this shell in competition some years ago, with each break featuring charcoal streamer comets with a different color scatter star. It was quite the crowd pleaser and took 1st place!

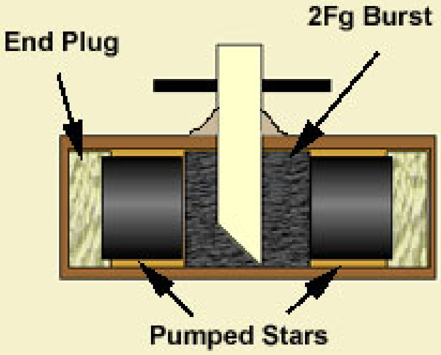

Figure 2: Scatter star components.

Figure 2 shows the basic components of a scatter star. They are really like a very short roman candle that fires out both ends simultaneously. Chinese scatter stars tend to use longer tubes with smaller diameter stars than those used here. They also make plastic moldings that feature stacked scatter stars that fire in alternating directions. A similar effect is depicted on page 264 of Shimizu's book Fireworks, the Art, Science and Technique. Here they are referred to as "ascending separating stars," since they are a grouping of scatter stars stacked on top of a shell to be used as a rising effect.

I have adapted these scatter stars to use typical go-getter type casings. The ones used here are item #T-137 tubes from Skylighter, which are 1-1/2" long x 7/16" I.D. x 5/8" O.D. One design issue with scatter stars is that the contents do not fill the entire length of the tube, so some filler must be used at each end. It really takes very little 2Fg black powder at the center to fire the stars, roughly 1/4 teaspoon. If the tubes are too short, then the stars won't travel as far. Thus the empty space at both ends must be plugged as seen in Figure 2.

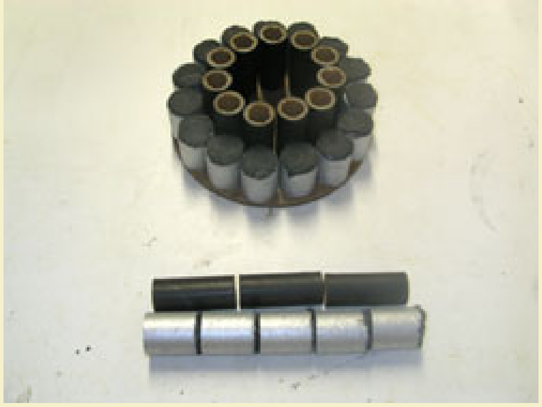

Figure 3: Trial fitting shell components onto a 4-1/2" dia. disk.

Since the scatter stars shown here will be used as insert shells, they must be able to withstand the breaking pressure of the shell they will be used in without prematurely igniting. If the shell breaks and one or two stars are seen right away, the surprise will be spoiled. The areas prone to gas leaks are the end plugs and the point where the time fuse penetrates the side wall.

The amount of confinement is also critical to making good scatter stars. Too much confinement can result in the thin casing bursting apart or blowing the stars blind. Too weak of confinement will not give the stars a good spread. Ideally both plugs will give away at the same time, although it is common for only one plug to blow out. When this happens, the effect is actually not ruined, since one star emerges burning in one direction while the casing with one star stuck inside travels in the opposite direction. The star actually burns inside the casing but is visible just as if it were correctly ejected.

The stars used for the scatter stars should have only very little clearance inside the casing. This insures that the stars will travel far and also prevents the central burst charge from migrating around the sides of the stars instead of remaining at the center where it needs to be. Pumped stars are the best choice for these, since they will travel farther than an equal sized round star. However, round stars are necessary for streamer to color effects, which make attractive scatter stars. Thus the break charge may be increased slightly over what is shown here when using round stars.

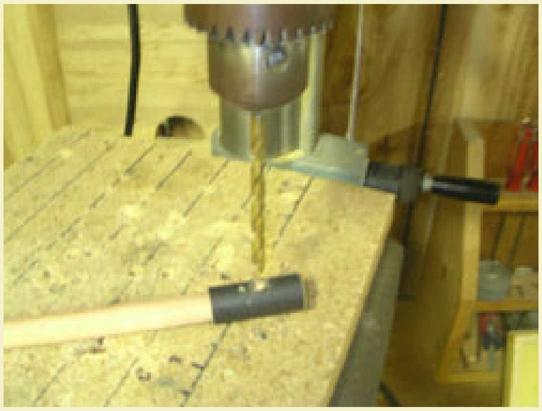
Figure 4: Drilling 7/32" time fuse holes at center of scatter star casing.

Because your comets and scatter star tubes may be different dimensions than shown here, it is important to trial fit all components before building this shell. Figure 3 shows how to make sure everything will fit by arranging the comets and inserts on the end disk used to build the shell (4-1/2" diameter in this case). Also stack your finished comets next to the scatter stars to figure out how many rows of comets you will need, as well as how long to make your shell casing. The comets used here are 3/4" diameter and 7/8" long. Thus the shell casing will be about 5-1/4" between the two inside end disks. Three rows of 10 scatter stars will require five rows of 14 comets in this case.

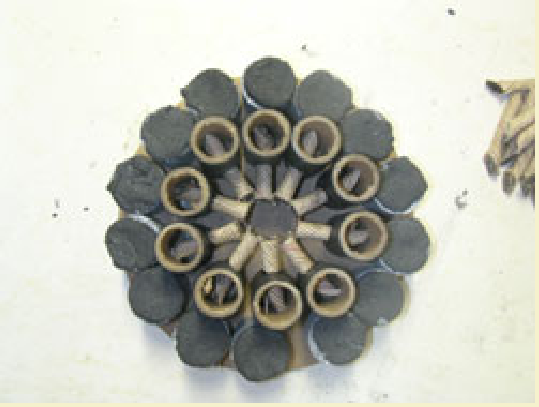
Figure 5: Determining maximum possible time fuse length.

First you will need to drill center holes in all your scatter star casings. For typical 1/4" Chinese time fuse, a 7/32" hole will make a snug fit. In order to prevent the inside of the casing from caving in when the drill bit punches through it, insert a snug fitting dowel rod in to the case when drilling, as seen in Figure 4.

Next you will want to determine your time fuse length, as seen in Figure 5. Nothing is worse than building a boat-load of tedious inserts only to find that their time fuse length prevents them all from fitting into the shell! Because of space limitations, you are really limited to about a two second maximum delay on the scatter stars. You can get around this limitation by using smaller comets, but 2 seconds is really a pretty good delay. Making the delay any shorter tends to lessen the scatter effect, since the stars will be firing closer and closer to the point where the shell broke instead of being able to drift out a good distance.

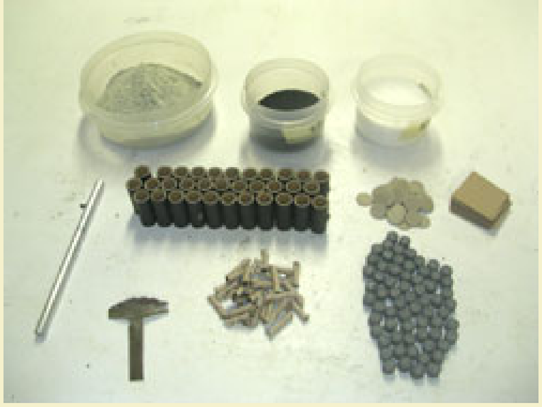
Figure 6: Scatter star components ready for assembly.

The time fuse is cut at a 45 degree angle for the end that will be inside the scatter star, while the other end is flush cut. The overall length used here is 1-1/8" end-to-end. You can cross match the time fuse, but the required offset from the end of the fuse will make your delay time shorter. Slurry priming the end of the fuse will give you the maximum delay possible, and is also faster than cross matching. It is better to create a ragged prime blob at the ends rather than a smooth one, since ragged surfaces take fire better.

Two methods are described here for making scatter stars. The difference between the two methods is in the way the end plugs are created. Both methods produce a good scatter star, but the second method using hot glue is considerably faster to construct.

Method 1:

First you will need some thin paper end disks that match the O.D. of your scatter star tube. I punched mine from chipboard using a hand held center-less punch. The disks are applied by dipping one end of the tube into a bowl of white glue, as seen in Figure 7, then applying the disk and allowing it to dry.

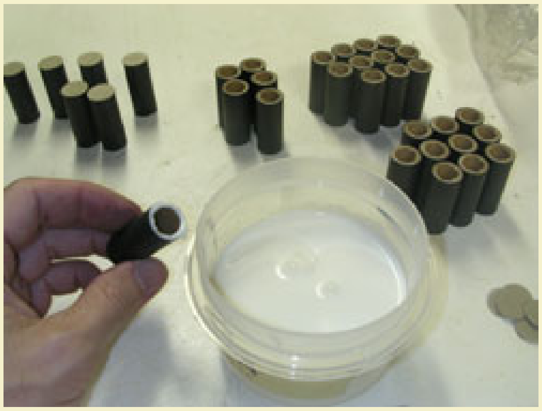

Figure 7: Dipping ends in glue bowl to fasten end disks.

Powdered clay is used as the filler at both ends of the tube. This not only has the purpose of filling the void, but it also serves to seal the end of the tube from possible gas leaks through holes in the glued seam. Fine sawdust can also be used in place of the powdered clay, but I find that the clay is easier to work with and makes a better seal. The amount of clay used is about 1/4 of a teaspoon.

Figure 8 shows a home-made scoop that is designed to allow easy loading of small tubes without the need for a funnel. This type of scoop comes in handy when loading a lot of tubes with small quantities of powder such as this. I originally saw this scoop design in a chemistry set I had as a kid, and had to rebuild it out of sheet aluminum after I lost the original scoop. It's one of those little things I just can't go without!

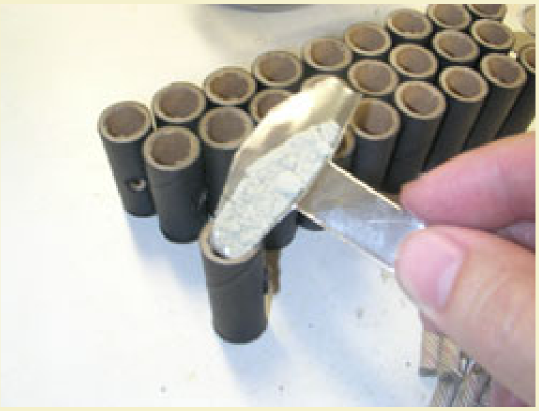

Figure 8: Padding with powdered clay. Note home-made scoop for easy loading without funnel.

After loading the fire clay increment into each tube, tamp it down with a rammer (do not pound it with a mallet), dump out the excess dust and then insert one of the pumped stars. It is faster to do a single operation on all tubes instead of building each scatter star from start to finish. Thus, after all the stars are inserted in all 30 tubes, proceed to insert the time fuse into all the tubes.

More...

Volume 4, Issue 4

5" Comet & Scatter Star Shell...

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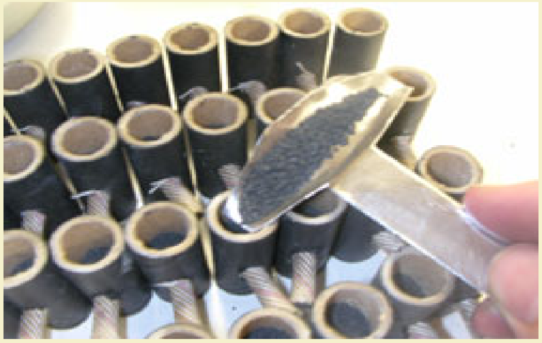


Figure 9: Adding center charge of 2Fg after inserting 1st star and time fuse.

Once the time fuses are all inserted, use the scoop again to add 1/4 teaspoon of 2Fg black powder into each tube. The second star is then dropped on top of this, and the remaining cavity is filled with powdered clay. The clay is just pushed down tight with your fingers, there is no need to ram it. Figure 10 shows half of the tubes finished off with the powdered clay. Note the close fitting stars in the tubes without the clay. These are the 3/8" pumped stars made as described here and primed in the NASCAR star roller to about 1/2" O.D.

Once the clay is in place, dust off the excess clay on the rim of the tube and then dip it in the white glue as before in order to fasten the remaining end disk.

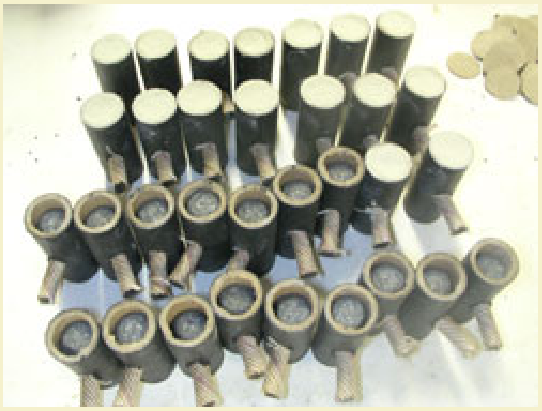
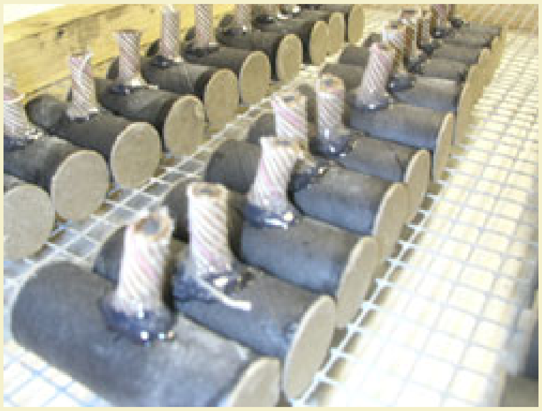


Figure 10: Padding the remaining space with powdered clay prior to gluing on second end disk.

Lastly you will need to seal around the joint where the time fuse enters the case. I advise not to use white glue for doing this, as this type of glue often forms pin holes upon drying and these holes will cause the tubes to fire immediately when the shell bursts. If you must use white glue, apply one bead and then apply a second bead after the first one dries in order to reduce the pin hole problem. Otherwise just use hot melt glue to seal the joints without any worries, as seen in Figure 11.

At this point the scatter stars are useable (after you cross match or prime them of course). Pasting a 1-1/2" square of thin, recycled kraft over each end will add further gas leak prevention and also increase the distance the stars will travel when they fire.

Method 2
The second method of producing scatter stars is similar to the way M-80s are mass produced. Both ends are plugged with hot glue, and that's it. The fixture shown in Figure 12 is for loading a single tube, but what you really need is a larger piece of wood with about 20 of these nipples in an array. This would greatly increase productivity, otherwise a single nipple can be used to produce one scatter star at a time, with an annoying wait for the glue to dry before removing each single device. The nipples do not need to be the exact I.D. of the tubes that will be placed on them, but they do need to be exactly 3/16" tall.



A star is placed on the nipple, then tube with the time fuse already installed is placed over it and onto the nipple. The burst charge is now added into the tube and then the other star is placed on top. Hot melt glue is then poured right on top of the star until even with the edge of the tube, as seen in Figure 13. When the glue solidifies, the tube is removed and then the void at the other end is also filled with hot melt glue. If you were loading many tubes at once on a pin array

Figure 11: Sealing around time fuse with hot glue.

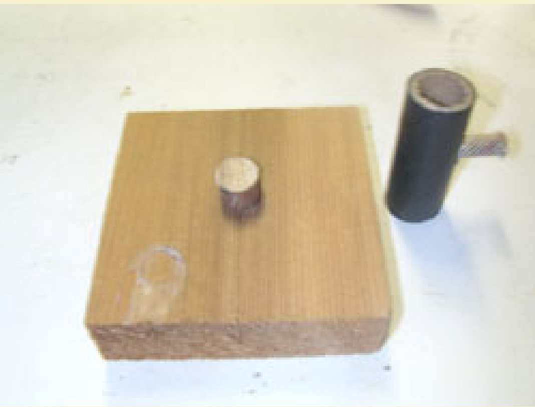


Figure 12: Loading fixture for the hot glue method.

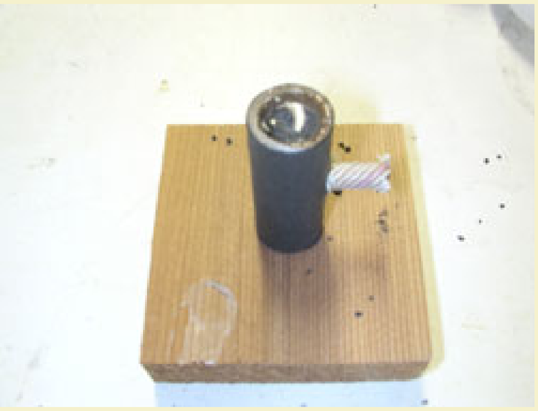


Figure 13: Hot glue used to fill ends of tube.

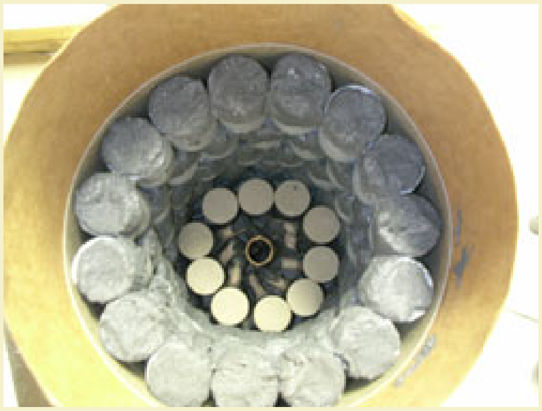


Figure 14: Inserting the scatter stars.

as mentioned, you would need to place a board on top of all the tubes and invert them all at once. After they are inverted, remove the pin plate from on top of them and hopefully you won't knock any over in the process.

That's it, you're done. Of course you just burned through a lot of hot glue, but at least you are not still punching disks out of a piece of cardboard, which is where you would be at right now if you went with the first method.

Loading the Shell

This shell is finished exactly the same as described here, except the color pistil stars are replaced by the scatter stars. The scatter stars are stacked the same way comets are, with each new row offset from the previous row to form a "brick wall" pattern. As the referenced article shows, only one turn of chip board liner is used in order to allow all the comets to fit snugly. Also note that the shell is built "upside down," meaning that the time fuse and pipette is installed at the bottom of the shell casing before it is loaded.

Because the scatter stars take up so much space, it is a good idea to load the break charge on top of each row as they are installed. This allows some break charge to settle in the gaps behind the tubes. Be sure to bounce the shell to make sure the burst charge settles down past all the time fuses. It also helps to pad a little between rows of scatter stars with some burst charge, but the extra space consumed by the padding must be allowed for when you cut the shell liner. It is easier to load the scatter stars after every couple rows of comets have been installed, instead of installing all the comets first and then trying to fit your hand down into the small hole to insert the scatter stars.

Charcoal comets work very well with this shell, since they allow the colored stars to show up well in contrast. Another interesting effect would be color comets with silver flitter or glitter scatter stars that fill the center with bright streaks of random trajectories.

Another interesting effect would be to load the shell with nothing but scatter stars, replacing the outer comets with scatter stars and then inserting the second inner row of scatter stars as well. The extra space may allow a 2.5 sec delay on the time fuse, creating a dark break followed by a swarm of scatter stars. I haven't tried it myself, but it's definitely on the to-do list. 🔥

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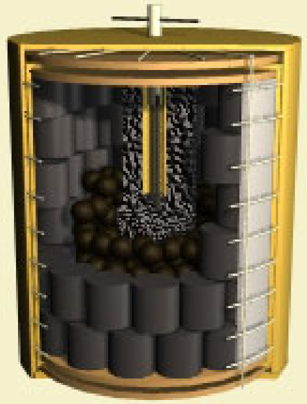
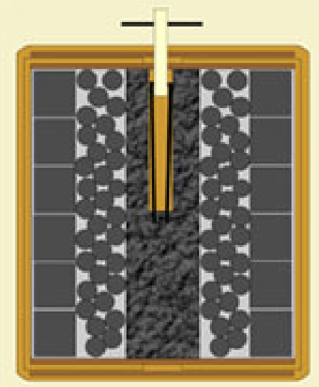
Volume 2, Issue 2

Build This...

5" Charcoal Comet Shell with Color Pistil





February, 2002 Issue

Build This:
5" Charcoal Comet Shell.

Design Notes:
Round Stars, Part I.

Autopsy:
Elephant Pattern Shell.

Class C Corner:
Air-Borne Art

Summary:
This shell breaks with big, bushy charcoal comets as a low intensity backdrop for a splash of vibrant color pistil stars. This is also referred to as a "double-ring" effect, although there really aren't any distinctly noticeable ring patterns. Making the comets will consume the majority of time spent building this shell, but the results are worth the effort.

Prerequisite: 4" Single Break Color Shell

Formulas: Tiger Tail, Blue, Red, Green, Purple

Materials:

- (3) strips 24" long x (comet height x row count) + 3-3/4" wide 70lb virgin kraft, grain short (case)
- (1) 23" long x (comet height x row count)+1/4" wide chipboard, grain short (liner)
- (3) 24" long x (comet height x row count)+6" wide strips 70lb virgin kraft, grain short (paste wrap)
- (1) 36" long x (comet height x row count)+10-3/4" strip of 30lb kraft, grain short (outer wrap)
- (4) 4-1/2" kraft or chipboard end disks, 1/8" thick
- (1) 2" piece of time fuse (2.2 ft/sec)
- (1) 3/8" ID x 2-1/2" long pipette (2-3 turns of 70lb kraft)
- (1) 5-1/2"" of 4 strand cross match
- (1) 1" piece of 4 strand cross match
- (1) 17" piece of 8 strand black match
- (1) 30" quickmatch leader
- (75 or 90) 3/4" comets

Tools:

- 4-1/2" dia. case former
- Rubber mallet
- 1-5/8" OD dowel or pipe
- Cross match punch
- 7/32" drill bit
- Hot glue gun
- 3/4" comet pump
- Brass hammer or 2 ton arbor press
- Scissors
- Anvil cutters

Unmeasured Materials:

3/8" stars(round or cut), flax twine, 2FA black powder, white glue or wood glue, masking tape, wheat paste

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5" Charcoal Comet Shell...

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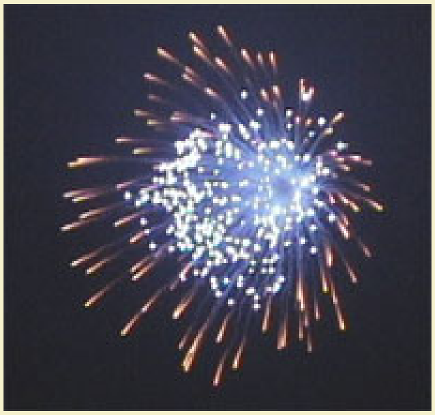

Figure 1: The comet shell built for this article.

Figure 2: A pair of commercial comet shells with large flitter comets.

Introduction:

Comet shells employ large, cylinder shaped stars which are formed by compressing damp composition in a sleeve using a plunger under high pressure. The size of the comets used in a five inch shell can range from 3/4" to 1-1/8" in diameter, depending on the effect that is desired. Larger comets are used to create long, drooping streamers due to the extended burn time of such large stars. Smaller comets allow more of them to fit inside the shell, and also leave extra room for other types of inserts that may form a second ring inside the comet ring.

For this shell, the comets will be 3/4" diameter, allowing 15 of them to fit snugly in each ring with no shimming required. When designing comet shells, you can use the Insert Calculator to see how many will fit inside the space you have to work with. The space required by the chipboard liner must be accounted for when using this tool, making the shell ID slightly less than the case former diameter.

This shell uses six rings of 15 comets, requiring a total of 90 comets. The comet composition used for this project is Shimizu's Tiger Tail, which is a slower burning charcoal streamer composition. The ingredients are not screened together, rather they are ball milled until a fine gray powder is obtained. Ball milling is necessary to achieve the fine tailed, bushy effect desired here. If the mixture is just screened together in the standard way, the comet tail will not appear as soft and dense.

Ball milling the comet mix also results in stronger comets after they are pressed. The larger the charcoal particles are, the weaker the comet will be. You should not be able to break the finished comets in half with your hands when they are dry, otherwise they will shatter when the shell bursts.

The comets used for this shell are 7/8" tall, resulting in about 156 comets per 1000g of Tiger Tail comp. You will get more or less depending on height differences between comet pumps. But while you are making comets, you might as well make enough for two or three shells. You weren't going to make just one were you?

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5" Charcoal Comet Shell...

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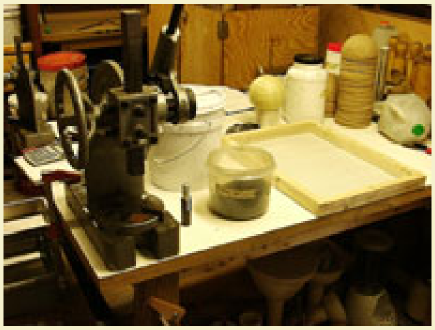

Figure 3: Arbor press, comet pump, comp bucket and drying screen.

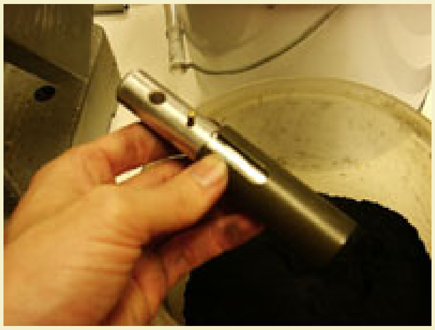

Figure 4: Keep pin 1/2" - 3/4" above sleeve when loading.

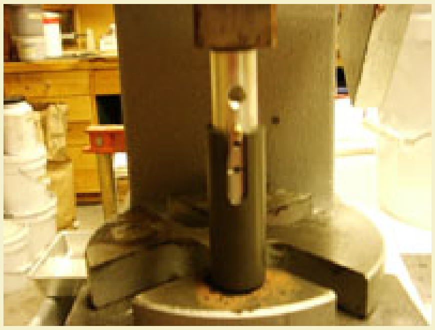

Figure 5: Pressing the comet.

Making the Comets:

The Tiger Tail composition should first be dampened 15% by weight with a mixture of water and 14% alcohol. Note that if you are using isopropyl rubbing alcohol, it is typically only 70% alcohol, thus you must use 20% in order to get the actual 14% alcohol/water solution. The alcohol helps speed the drying of the comets, and also lowers the surface tension of the water, which helps the water disburse into the composition with less effort.

The composition must be thoroughly kneaded with the hands after the water/alcohol mixture is added. The water will tend to form clumps that are over saturated with water, and these must be broken up continuously in order for the water to disperse evenly throughout all the powder. Some builders will run the composition through a coarse screen several times during mixing to help break up the clumps, which speeds up the mixing process. Another method involves compressing the damp comp down into a solid cake, then let it set for several minutes to allow capillary action to distribute the water evenly. Note that this later method should not be used when there is risk of an aluminum-nitrate reaction, as the solid block of comp will retain heat and accelerate the reaction.

Once the composition is properly dampened, an amount squeezed in the palm of your hand should form a clump that easily breaks in half when crushed with your thumb. It should not crumble back into powder, but it should not deform like clay either. Once this consistency has been reached, the dampened comp should be placed in a container with a lid to prevent the alcohol from evaporating until it is ready for use.

There are two varieties of single comet pumps that are commonly used to make comets. The simplest involves a short tube with a plunger that fits inside. The plunger is marked with a line at one end, which is used as a gauge to keep all comets the same size. The second type of comet pump has a slotted sleeve to accommodate a plunger fitted with a pin, as seen in Figure 4. This pin is used to gauge the length of the comet, as well as preventing the plunger from dropping through the sleeve when the comet is ejected.

The pump is first loaded by holding the plunger so that the pin (or line) is about 5/8" above the end of the sleeve as shown in Figure 4, then repeatedly rammed into the damp comp until no more will pack into the sleeve.

Once loaded, the composition is consolidated by placing the pump on a hard surface and applying force to the plunger. This can be done with a brass hammer, hard plastic mallet or a 2 ton arbor press. The arbor press makes the work go slightly faster, produces considerably less noise and requires less effort. The arbor press shown in Figure 3 features a ratchet lever with a plunger wheel that allows the user to quickly position the plunger on top of

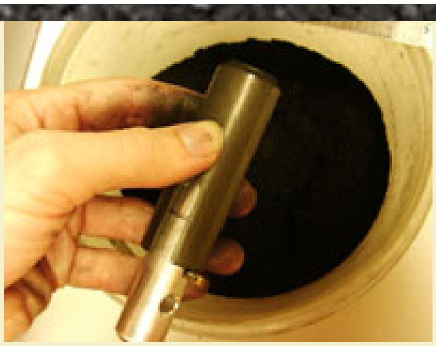

Figure 6: Push pin down to sleeve and cut off excess comet.

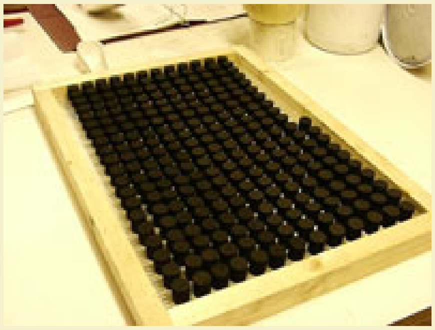

Figure 7: 250 comets ready for drying.

the pump so that the pull lever is always at an angle of optimum leverage.

When using the pin type pumps, it is important to make sure the pin is always aligned above the slot in the sleeve, as shown in Figure 5. Failure to do this can result in the pin being sheared off or bent, with possible damage to the sleeve. If the pump was loaded properly, the pin will stop short of the sleeve when the comp is fully compressed. If the pin enters into the slot after pressing, then the comet will be too short and must be scrapped back into the comp bucket.

After pressing, the plunger is rotated so that the pin is no longer over the slot, as shown in Figure 6. The plunger is then pressed until the pin contacts the sleeve. For pinless pumps, the plunger is pressed until the engraved line is aligned with the edge of the sleeve. A thin blade is then used to shave off any part of the comet that extends beyond the bottom of the sleeve. This step is important for insuring that all comets are the same height.

Finally the plunger is rotated so that the pin is aligned with the slot again, then the comet is ejected onto a drying screen. The comet should be reasonably strong at this point, such that it won't easily crumble if squeezed between the fingers. If the comet is dropped onto a hard surface from a height of three to four feet, it should not break apart into many pieces. Should this happen, then the comet comp needs more water.

Once you get the hang of it, you should be able to pump out about 100 comets per hour. Figure 7 shows several hours worth of work ready for drying.

More...

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5" Charcoal Comet Shell...

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Loading the Shell:

Before you start cutting any paper, you need to determine the height of the inside of the shell by placing five or six comets (depending on how many rows you want in the shell) end to end and measuring their length. The height of the chipboard liner should equal this distance plus an additional 1/4 inch. The following table shows how all the material sizes can be calculated from the height of the comets you are using.

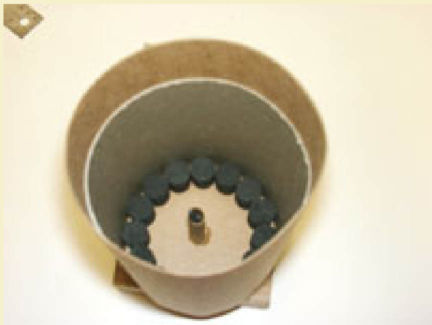

Figure 8: Loading in the first row of comets.

Layer	Paper Dimensions
Case	H + 3-1/4" x 24" long (three strips)
Chipboard	H x 23" long (23" will vary slightly)
Paste wrap	H + 5-3/4" x 24" long (three strips)
Finish wrap	H + 10-1/2"" x 36" long

H = comet height x number of rows + 1/4"

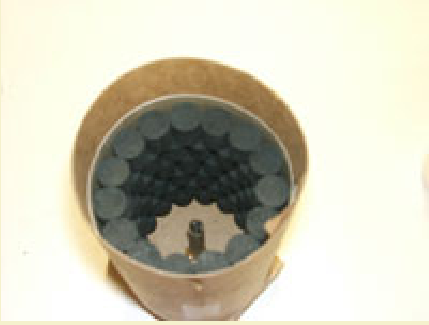

Figure 9: All comets tightly packed into six rings.

The former used for 5" shells should be 4-1/2" diameter and about 12" long. Roll up the three kraft strips and pleat in a fused disk as described in the 4" Color Break Shell article. Allow 1-5/8" of paper to extend beyond the end of the case former before inserting the end disk and pleating.

The key to building this shell is to insure that the comet rings fit as snugly as possible up against the wall of the shell. In order to achieve this, it is necessary to calibrate the inside diameter of the shell by adjusting the length of the chipboard liner. Start with two full turns of chipboard and insert a single row of comets as shown in Figure 8. The last comet should be difficult to squeeze into place, and the comets should remain wedged in place when the shell is inverted. If you are not able to insert the last comet, remove the chipboard liner and trim a few inches off its length. Refit the comets again to see if the 15th comet can be wedged into place. Continue trimming the liner until the ring can be completed.

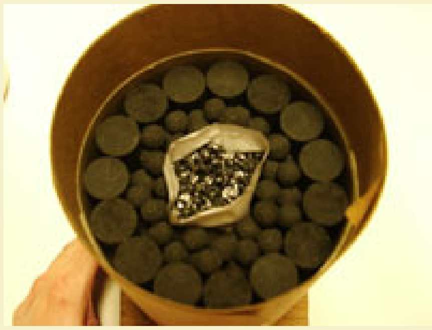

Figure 10: Center filled with break charge and round color stars.

An alternative to this method of fitting the comets involves rolling a turn of chipboard around the former before rolling the case over it. This will slightly enlarge the diameter of the case, allowing the liner to consist of two full turns of chipboard. While trying to determine how much chipboard to roll around the former, you can let the case overhang enough to test fit a small liner and a single row of comets while the case is still on the former. This way you can determine the fit without having to pleat in a disk.

Another method of keeping the comet rings tight without customizing the inside diameter of the shell is to wedge small shims of wood between the comets. When the last star won't fit, the empty space is divided around the ring such that small wedges of wood can be used to make the ring tight. Anywhere from one to four wedges may be required, depending on the size of the wedges and the space to be filled. Some builders also use crushed

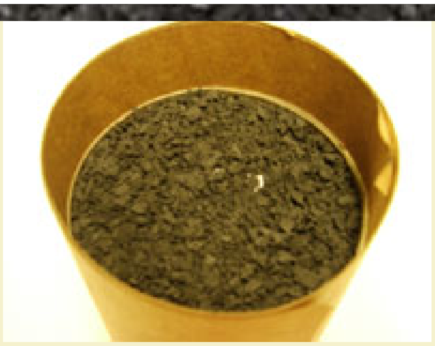

Figure 11: Remaining space filled with rough powder.

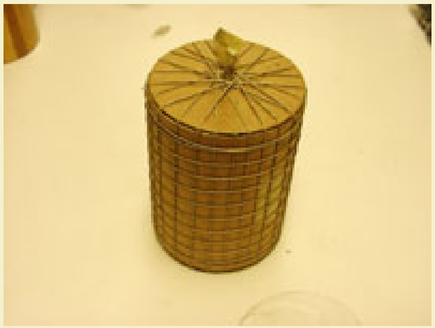

Figure 12: Spiked and ready for pasting.

tubes wedged into the cavity to lock in the ring.

It is common when loading larger comets to pack sawdust down into the small spaces between the comets and the shell wall. This process can be tedious, but results in a more symmetrical spread of the comets when the shell breaks. However, as seen in Figure 1, omitting the sawdust still results in an acceptable break when the comets are packed tight enough. The symmetry requirement that warrants the use of sawdust becomes more important when single rings of large comets or inserts are used.

After the comet fitting trial and error is complete, the rest of the comets may be loaded into the shell. Each new row of comets should be offset from the previous row by 1/2 a comet diameter, so that the comets stack like bricks in a wall. Figure 9 shows the shell fully loaded with comets.

The 3/8" stars that are to be loaded between the comets and the burst core are most effective if they exhibit pure colors with a lower amount of light output. This is so that they do not overpower the charcoal streamers, which do not put off much light. Any of the formulas given on the materials page will work well here.

There are a few ways you can load the inner ring of stars and burst charge. The traditional method involves inserting a thin-walled metal pipe known as a "canulle" into the center of the shell and pouring the stars around the outside of it. The burst is poured into the canulle pipe, after which it is slowly removed.

I find the tendancy for the canulle to get stuck by the binding action of the stars makes this method rather difficult at times. My own method involves creating a thin walled burst bag from two turns of thin tissue paper rolled around a length of 1-5/8" O.D. PVC pipe. The tissue is folded around the bottom of the pipe, which is then inserted over the time fuse and pushed to the bottom of the case. The pipe is slowly removed and the bag is filled to the height of the comets with 2FA burst charge. The tissue bag should extend about an inch above the powder charge so that it may be folded over when filled. The stars are then poured around this cylindrical burst core until they reach the level of the comets, as shown in Figure 10.

The space between the comets and the top of the chipboard liner is filled with rough powder, which is made by granulating damp meal powder (with 5% dextrin added) through a coarse screen. The purpose of this gravel-like filler is to provide non-compressible structural support between the bottom of the case and the rest of the contents. If the contents of any canister shell do not provide a continuous line of structural integrity, there is the risk that the shell could compress slightly under the large forces exerted on the casing when it is fired from the mortar. This compression would cause the shell walls to split open and flowerpot immediately.

This shell is closed and finished in the same way described in the 4" Color Break Shell article. The only difference is that it is spiked with 24 vertical strands of twine instead of the 16 used for 4" shells. The paste wrap also requires three 24" long strips instead of two. The easiest way to determine the width of the paste wrap is to use a long, thin strip of paper to measure the distance from the time fuse, down the side of the case and around to just beyond the center of the bottom disk.

Depending on the type of stars and number of comets used, this shell will weigh around 1500 grams. Using the ounce per pound rule for calculating the lift charge would require 93 grams of 2FA.

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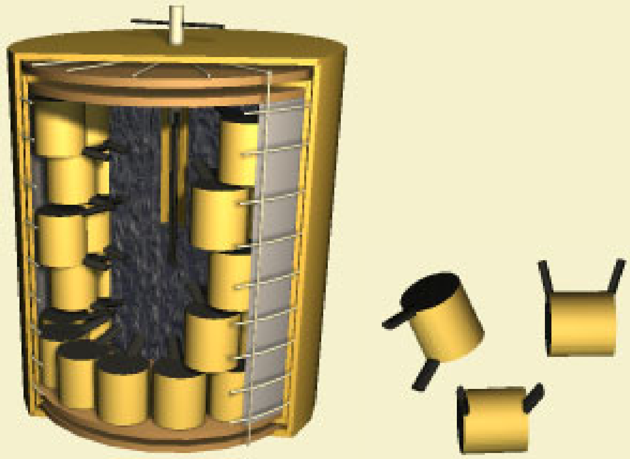
Volume 5, Issue 2

Build This...

5" Pill Box Star Shell



April, 2005 Issue

Build This:
5" Pill Box Star Shell

Design Notes:
Pyro Shop Design

Tool Tip:
Shell Builder's Workbench

Accident Analysis:
Ball Milling

Class C Corner:
Mayhem,

Summary:

Pill box stars, also called box stars, are a unique type of star that burn very brightly for a longer duration than a comet star of the same size. They are usually metal fueled color stars, with long illuminated smoke trails behind them as they burn through the sky. Because of the extended burn time, which results from the paper sleeve around the star that prevents it from igniting on all sides, these stars will droop like parachute flares and are generally fired as single break color shells. This article explains how to make pill box stars and then produce a typical 5" color shell with them.

Formula: John Albert's Green Pill Box

Materials:

- (3) strips 24" long x (star height x row count) + 3-3/4" wide 70lb virgin kraft, grain short (case)
- (1) 23" long x (star height x row count)+1/4" wide chipboard, grain short (liner)
- (3) 24" long x (star height x row count)+6" wide strips 70lb virgin kraft, grain short (paste wrap)
- (1) 36" long x (star height x row count)+10-3/4" strip of 30lb kraft, grain short (outer wrap)
- (4) 4-1/2" kraft or chipboard end disks, 1/8" thick
- (1) 2" piece of time fuse or spolette w/3.5 sec delay
- (1) 3/8" ID x 2-1/2" long pipette (2-3 turns of 70lb kraft)
- (1) 5-1/2"" of 4 strand cross match
- (1) 1" piece of 4 strand cross match
- (1) 17" piece of 8 strand black match

Tools:

- 4-1/2" dia. case former
- Rubber mallet
- 20" long x 3/4" OD dowel or pipe
- Cross match punch
- 7/32" drill bit
- Hot glue gun
- 3/4" pillbox tool (optional)
- paper cutter
- Scissors
- Anvil cutter w/length gauge

- (1) 30" quickmatch leader
- (7) 5" x 12" sheets 60-70 lb kraft, grain long
- (70) 2" long sticks of black match
- (700 gram) pillbox star composition

Unmeasured Materials:

flax twine, 2FA black powder, white glue or wood glue, masking tape, wheat paste

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5" Pill Box Star Shell...

Page 2

Introduction

Pill box stars, also called box stars, seem to get little attention compared to the more popular cut, pumped and round stars. Pill box stars have been around a long time and have some distinct advantages over other types of stars. Because pill box stars are packed into a thin paper tube, they are stronger than regular pumped stars (comets) and can thus withstand stronger shell bursts without being pulverized. Pill box stars are "primed" using a built-in strand of black math, which results in much better ignition and less blind stars even when thrown from the shell at very high velocities. Since pill box stars are stacked along the sides of a shell just like pumped stars are, they offer the same structural integrity of pumped stars.

The performance of a pill box star is similar to a large pumped star, except that they tend to burn for a longer period of time due to the paper wrapper which prevents it from taking fire on all sides. A pill box star can be spotted by its brilliant light output, sparser star density, long burn time and the illuminated smoke trails that produce a drooping willow effect (see Figure 15 at end of article). This is a distinct effect that is not really produced by any other type of star.

To the first time observer, a pill box star appears to be some kind of insert or a pasted in comet. However, these stars are really quite simple to make and can be nearly as quick to produce as pumped stars made with a comet pump. Best of all, you don't need any special tooling other than a wooden dowel rod!

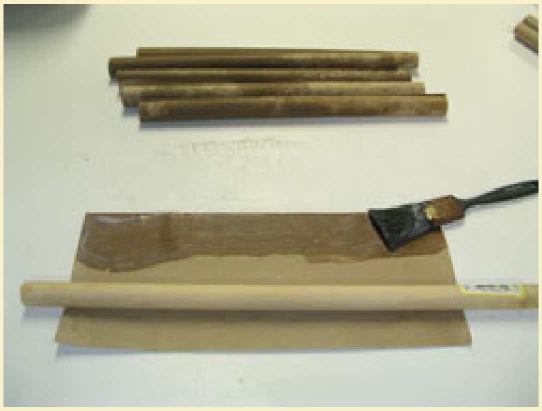

Figure 1: Rolling 12" long tubes, 2 turns 60 lb kraft.

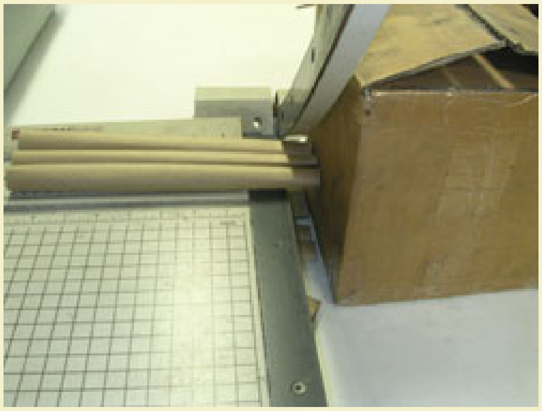

Figure 2: Cutting dried tubes into 1" long segments using a paper cutter.

Making Pill Box Stars

Pill box stars look like regular comets that have been pasted in with a few turns of paper, but the paper sleeves are actually rolled first and then charged with composition afterwards. So the first step is to produce many tiny paper tubes that are the same diameter as the stars you are making, ¾" in this case.

When making pill box tubes, it is much quicker to roll long tubes and then cut segments from them. The tubes rolled here will be 12" long and ¾" I.D., using two turns of 60 lb kraft. The paper can be recycled kraft, and even grocery bags will work. Start by preparing several strips of kraft measuring 5" wide by 12" long, with the grain running in the long direction. Having the grain run parallel to the length of the tube is important, since it allows the tube to be rolled much easier and prevents it from warping when the paste dries. If your tubes are bent upon drying, you miscalculated the grain direction.

The tubes are made by pasting half the sheet of paper as seen in Figure 1, then rolling them as tightly as possible around the dowel.

Making the tubes any longer than 12" can make this step hard. Note that white glue can be used in place of wheat paste, but the wheat paste is much faster to apply and the finished tubes are a little better quality.

These tubes can be dried in a drying box in about an hour or so, otherwise you can put them out in the sun for half the day or use a fan to help speed up the drying process.

Once the tubes are dry, a paper cutter is used to cut two or three at a time, making one inch long segments. A heavy object such as a box can be used as a depth gauge when cutting, as seen in Figure 2. Make sure both the box and the paper cutter don't slide around when using this method. The tubes will get squashed flat a little when cut, but this doesn't matter.

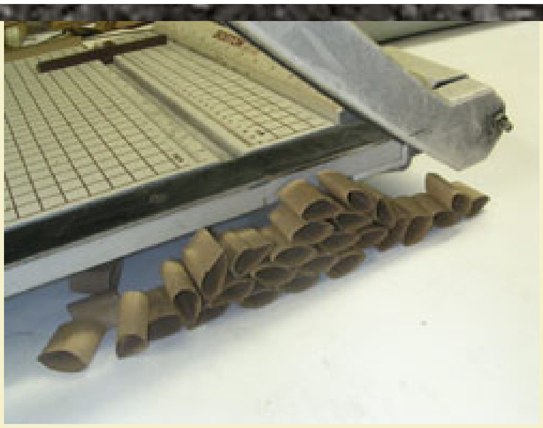
Figure 3: Cutting process tends to flatten tubes a little.

Pill box stars take fire from a stick of black match that runs up the side of the star, with a least ½" of match sticking out at both ends. Thus you will need to prepare at least 70 sticks of black match that are 2" long to build the pill box shell. This is a great use for those excess pieces of black math leftover when building other devices (you know, the ones that are too long to throw away but too short to fuse or lift any shells with). The anvil cutter with length gauge shown in Figure 4 makes the job of cutting all the match go pretty fast.

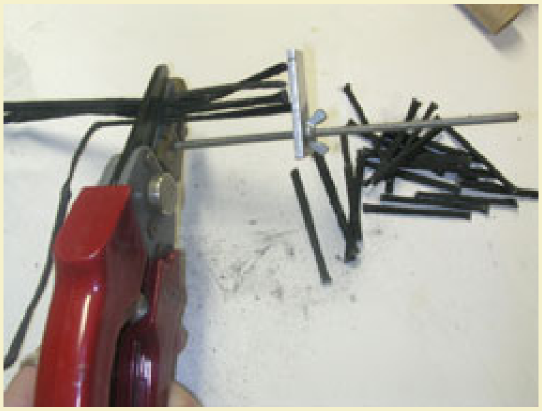
Figure 4: Using the anvil cutter with length gauge set to 2" for cutting 70 sticks of black match.

Note that the quality of your black match will make or break your pill box stars. Because the match will be severely bent on each end where it contacts the star, poorly made black match with only a shell of powder coating the outside of the string will result in many blind stars. If your match turns into floppy white string at the bending points, read here about how to make good quality black match first.

The composition you will be using needs to be dampened about 8 to 10 percent, depending on the formula. There are many formulas on record that are specific to box stars, but there is no reason you can't use any star formula you want. Most metal fueled bright colors look good, and you can use streamers as well. The break in Figure 15 is using the Buell Red magnalium fueled formula, which is not specific to box stars. There is some debate about weather box star compositions should burn slower or faster than normal star compositions, but really it all depends on how long you want your stars to burn.

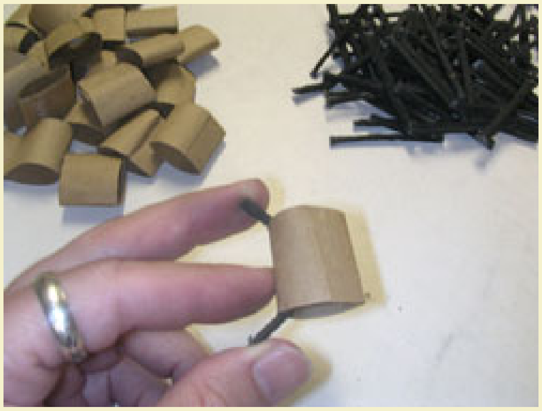
Figure 5: Inserting a stick of match and bending the ends to hold it in place during loading.

Pill box stars are not primed, so you don't have to worry about fancy primes for hard to ignite formulas. The black match burning across the edge of these stars is very effective at igniting almost anything you use. If you are making chlorate box stars, then using KP match for the fuse would be a good safety measure, even though BP match has been used for chlorate stars in the industry for years. If you are using a hard to ignite formula such as a KP/Aluminum flitter, then KP match can also be used to provide a hotter flame for better ignition.

The formula being pressed into stars here is the Green Pill box MgAl #2 from John Albert, and was dampened with 10% water. You will need to prepare about 700 grams of this formula to make all 70 stars plus a few extras for testing. This is an excellent formula by the way, with minimal ingredients, no chlorate and awesome color quality. There are no orange sparks or yellowish magnalium fallout trailing behind these stars, only pure green floating through the sky! The color may look pale when testing on the ground, but this is typical with bright colors and they will look a deeper green when viewed a few hundred feet up in the sky.

To load the pill box sleeves, start by inserting a stick of match and bending the ends as seen in Figure 5. Pinch the match between your fingers and use it to hold the tube while scooping it into your damp powder bowl. As you scoop the tube to fill it up, use you're your thumb and finger to compress the powder solidly into the tube. Keep scooping and pressing until the tube is full. You may also need to squeeze the side of the tube to get it back into a round shape if it is still oval shaped after loading.

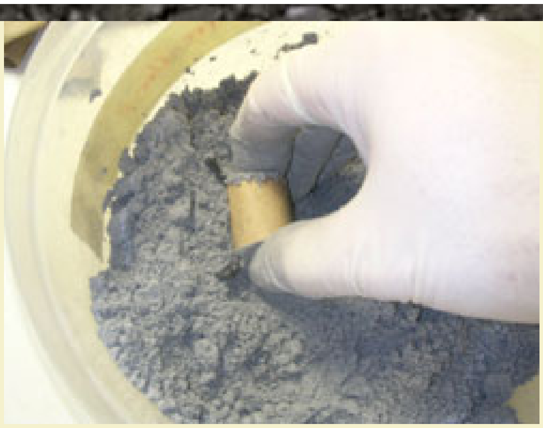
Figure 6: Scooping up damp composition and pinching it into the tube.

At this point there are two schools of thought, and you can just choose the one that you prefer. Traditional texts just describe pinching the powder in by hand and that's it, you're done. However, other people prefer to lightly consolidate the composition further using light taps from a lightweight mallet. This is done to remove any possible air gaps and produce a stronger star. This no doubt results in better quality, but might not really be necessary.

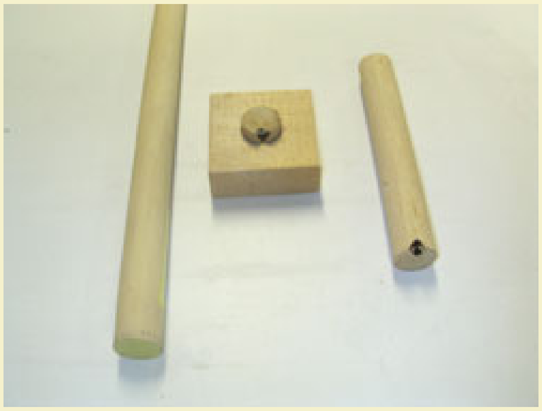
Figure 7: A slotted nipple and rammer for consolidating comp after loading.

If you want to consolidate the star comp further, you will need to build the simple wooden tool shown in Figure 7. This consists of a small nipple about 1/8" tall and a matching rammer that is about 5" long. Both the nipple and the rammer have a small notch cut in the side so that they can accommodate the match sticking out from the pill box star. Figure 8 shows how the star is placed between the nipple and the rammer, then tapped a few times with a rubber mallet. You are not whacking drivers or pumped stars here, only a few light hits is all it takes.

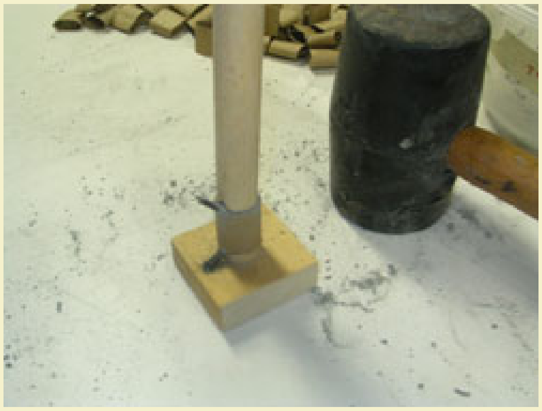
Figure 8: A couple of light taps from a rubber mallet for additional consolidation.

That's all there is to it, just make 69 more of them plus a few extras for testing and set them aside to dry. Using the Passfire drying box I was able to dry these stars to a usable state in just 24 hours, although it is probably best to dry them at least 48 hours when force drying them. Otherwise air drying can take a week or more.

More...

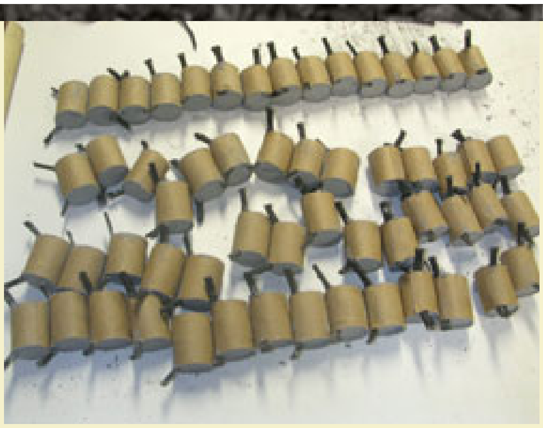

Figure 9: Completed pill box stars ready for drying.

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5" Pill Box Star Shell...

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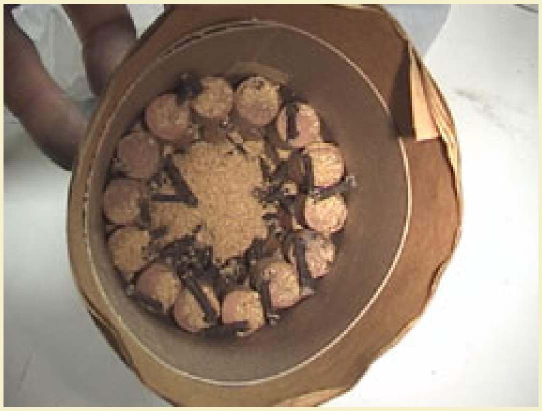


Figure 10: Loading rows of 14 pill box stars, using sawdust to pack in the gaps behind them.

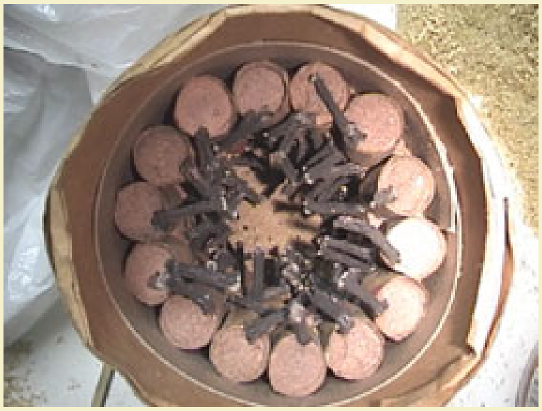
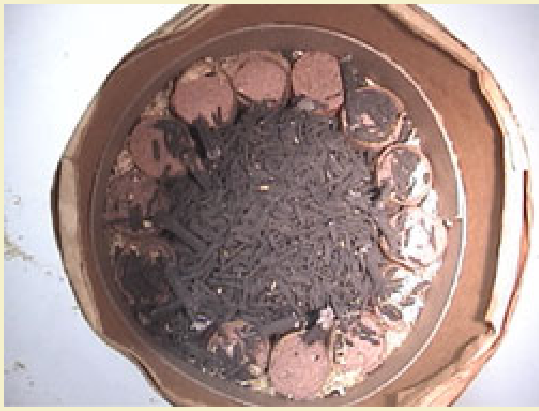


Figure 11: After all five rows are "dusted" in, the shell should be tight and resistant to bending.



Making the Shell:
The casing for this shell is produced in the standard way for a 5" canister shell, using 5 turns of 70 lb kraft that is 3" longer than the length of five pill box stars stacked end to end. If five of you stars measure 5 ¼" long, then you can roll the case from 5 turns of paper measuring 8 ¼" wide. The inner chipboard liner would then be rolled from one turn of 5 ¼" wide chipboard.

Normally two turns would be used for a typical canister shell, but one turn was omitted in this case in order to allow 14 stars to fit tightly into each row. If two turns of chipboard were used, you would have to use 13 stars and then shim a lot of extra space leftover between the stars.

The chipboard liner shown in the pictures was actually too tall for this shell and had to be cut down before the shell was closed. You don't want to have the excess chipboard seen above the last row of stars as seen in Figure 11 and 12, so be sure to measure a stack of five stars first in order to avoid this problem. A slight overhang is fine and can be fixed by filling the excess space with rough powder, but the overhang seen here is really too excessive for that.

This shell is loaded with five rings of 14 stars each, for a total of 70 stars. The stars are loaded so that the match strands all face inward, as seen in Figure 11. The first row of stars, which must sit on the bottom disk, need to have the bottom piece of match bent at a severe 90 angle so that the stars can sit flat. Some builders will clip the bottom piece of match off altogether to avoid this problem, which is probably the best approach.

Each ring of stars should be packed in using sawdust tamped into the space behind each star and the shell wall, as seen in Figure 10. You can actually be quite sloppy with the sawdust when pouring it behind the stars, since the stars will be locked in place when you are done so that you can turn the shell upside down to dump out the excess sawdust.

As when building comet shells, each row of pill box stars should be placed over the joints of the previous row, just like when building a brick wall. This is even more important with pill box stars, since the strands of match prevent stars from sitting directly on top of each other.

If properly consolidated with sawdust, the shell should hold its round shape when squeezed from the sides, rather than easily distorting into an oval shape.

Figure 12: Filling the remainder of the shell with burst charge.

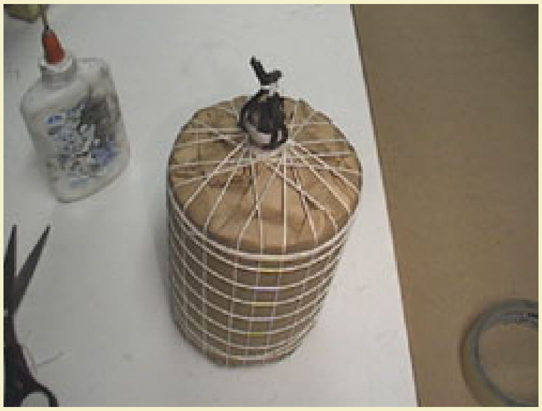


Figure 13: This shell was finished using unpasted paper followed by another layer of spiking, known as the "rinfasciature" method.

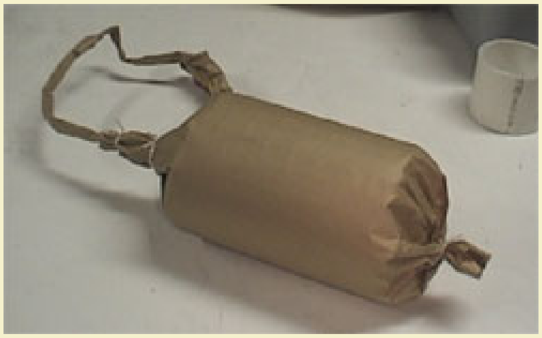


Figure 14: Completed shell ready for firing.

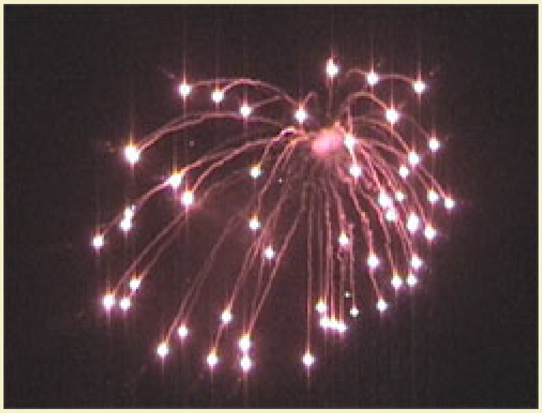


Figure 15: The brilliant stars bursting from the red pill box shell shown above.

There are a variety of break charges you can use with this shell, due to the fact that these stars take fire very easily and they are not easily blown blind or pulverized. The break charge cavity is rather large to be filled with straight 2FA, although you could do that if you want. This shell could be broke with rough powder if your rough powder is strong enough. For the shell shown here, the burst charge is KP on rice hulls in a 6:1 ratio. You could also use KP on puffed rice or BP on puffed rice as well. These different charges will just change the burst diameter, with KP giving the larger breaks.

The shell shown here was fused using a traditional spolette with a 1 ½" powder charge. Chinese time fuse could also be used.

The spiking was done with a double strand of 8-ply cotton, with 32 verticals instead of the normal 24 of single strand when using a good flax twine. The horizontal spiking was spaced so that equal squares were formed when crossing the vertical threads.

Normally this shell would be pasted in with 5 turns of pasted 70 lb virgin kraft, but for the test done here a prototyping method known as "rinfasciature" was used so that the shell could be fired the same day it was built. This is a construction technique where the shell is not actually pasted in, rather it is "pasted" with dry paper and then spiked a second time, as seen in Figure 13. The second layer of spiking gives the added strength that is lost from not using pasted paper. While this method is more time consuming and costly, it does allow you to fire a shell the same day you make it and produces break patterns that are usually as good as if you had pasted the shell in the normal way.

Because pill box shells are very light for their size, the standard rule for calculating lift charge (1 oz of lift per pound of shell weight) can not be used here. At least 2 ½" oz of lift should be used for this shell.

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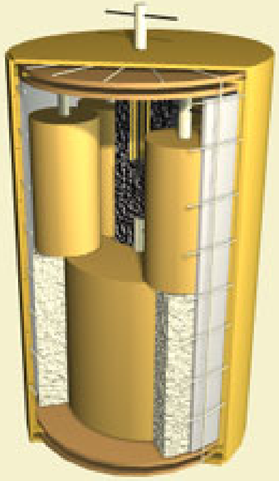
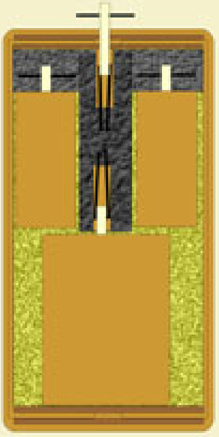
Volume 5, Issue 5

Build This...

5" Rondelle w/Bottom Shot





November, 2005 Issue

Build This:
5" Rondelle w/Bottom Shot

Beginner Project:
Smoke Bombs

Technique:
Coating Magnesium, Part I

Tool Tip:
Hemisphere Center Marker

Autopsy:
45 mm Italian Candle

Summary:

The Rondelle is a classic canister shell that bursts with a ring of timed reports which fire sequentially in a clockwise or counter clockwise progression. The effect is usually terminated with a final bottom shot when the ring has completed.

This article describes how to build a simple rondelle using time fuse as the timing mechanism. Various methods of constructing bottom shots are also covered, with a detailed description showing the easiest and most economical method.

Materials:

- (3) strips 24" long x 11-1/2" wide 70lb virgin kraft, grain short (case)
- (1) 23" long x 7-1/2" wide chipboard, grain short (liner)
- (3) 24" long x 13-1/2" wide strips 70lb virgin kraft, grain short (paste wrap)
- (1) 36" long x 18-1/4" strip of 30lb kraft, grain short (outer wrap)
- (4) 4-1/2" kraft or chipboard end disks, 1/8" thick
- (7) 1-1/4" O.D. x 1" I.D. x 2-1/2" long slaute tubes
- (7) 5" wide x 8-1/2" long 70lb kraft)
- (7) 4-1/2" x 8-1/2" long 30 lb recycled kraft
- (1) 5-1/2" wide x 17" long 60 lb recycled kraft
- (1) 5" wide x 18" long poster board, grain short
- (1) 3" wide x 28" long poster board, grain short
- (4) 2-1/2" chipboard end disks, 1/8" thick

Tools:

- 4-1/2" dia. case former
- Rubber mallet
- 1" OD dowel with 5/16" hole in one end
- Cross match punch
- 7/32" drill bit
- Hot glue gun
- 1/2" x 12" long tamping rod
- 1/8" x 6" long tamping rod
- 2-1/2" case former
- Anvil cutters
- Scissors

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Volume 5, Issue 5

5" Rondelle w/Bottom Shot...

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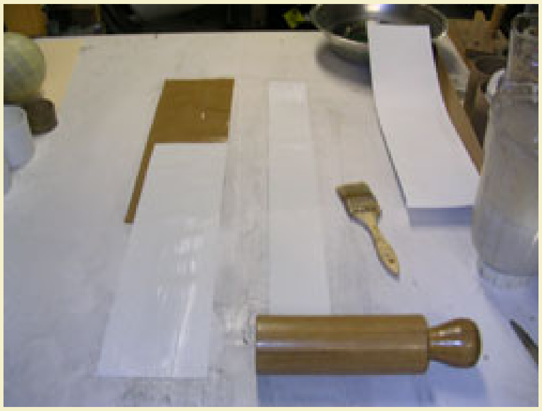


Figure 1: Ready to roll a bottom shot.

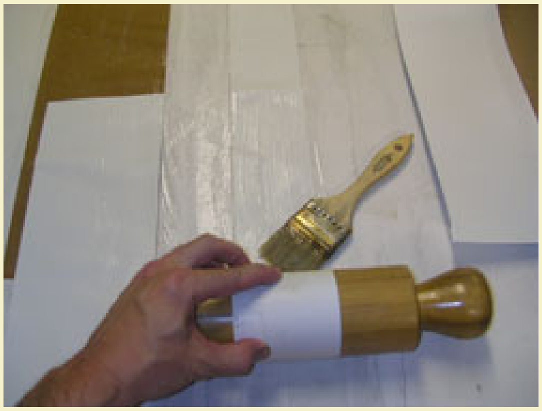


Figure 2: Pasting the inner case.

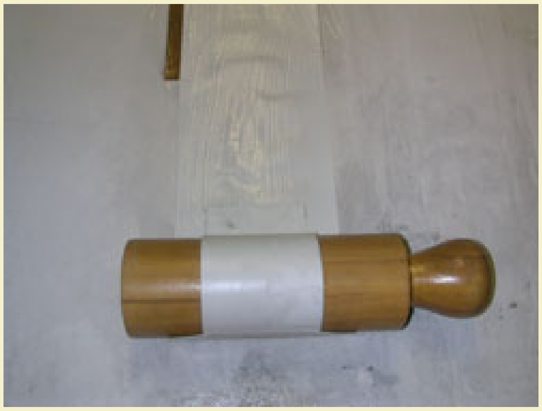


Figure 3: Centering the inner case when rolling the outer case.

Introduction

This shell reminds me of a T-shirt I once saw at a fireworks convention which contained the following shell performance description: "Salutes to reports to bottom shot." The shirt was of course poking fun at how many names we have given to things that simply go "BANG!" The rondelle fits into this class of shell known as "timed reports," which contain nothing but sound producing effects. Since there are no visual effects other than the flashes of white light, the shell is suitable for display in both daylight and at night. In fact, the puffs of white smoke left behind actually make daylight viewing more entertaining, as anyone who has witnessed the barrage of such shells that occur at dusk during any PGI convention can attest. The puffs of rolling white smoke create a static image of the shells performance suspended in space, drifting off with the wind like credits at the end of a movie.

Although this shell contains nothing more than flash powder and black powder, the effect is not a trivial one to achieve. A successful rondelle requires the builder to demonstrate three things: 1) the ability to produce well-made salutes that do not detonate when the shell breaks, 2) the ability to produce accurate and evenly paced timings and 3) the ability to keep track of multiple timed devices during construction so that they are properly loaded. This last one may seem like a no-brainer, but I can't tell you how many times I've seen a "rondelle" where the reports randomly jumped around in the ring rather than follow the required circular progression.

Because this shell does demonstrate the essential skills mentioned above, it is a good one to include in your lineup when competing in shell competitions. The shell described here uses a 3" bottom shot, which keeps it within the accepted guidelines for anyone wishing to use it as a PGI competition entry. The shell seen in the pictures was actually fired as part of my Level 3 shell competition for PGI in 2005, which took 1st place.

Bottom Shot Construction

A defining feature of bottom shots is a very strong case wall, which is necessary both to produce a loud report as well as withstand the high compression forces during lift. Since bottom shots are usually located at the bottom of multi-break shells with lots of weight above them, they are subjected to more compression during lift than other shell components are. A flimsy bottom shot such as one made from a thin-wall spiral wound tube or, even worse- using a standard shell casing simply filled with flash, runs the risk of crumpling under pressure, which can cause the outer shell casing to rupture and cause a detonation that usually destroys the mortar and sometimes even nearby mortars. Canister shells with bottom shots produce the most

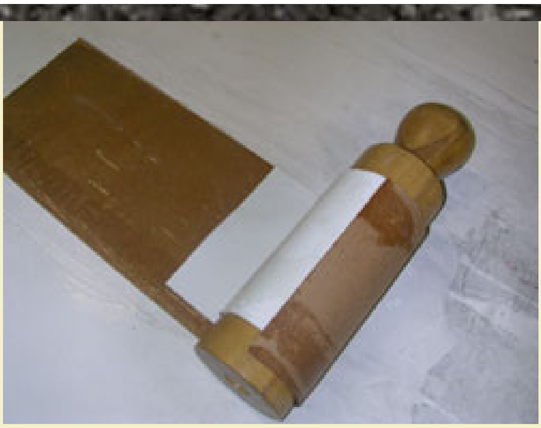


Figure 4: Rolling the final outer layer.

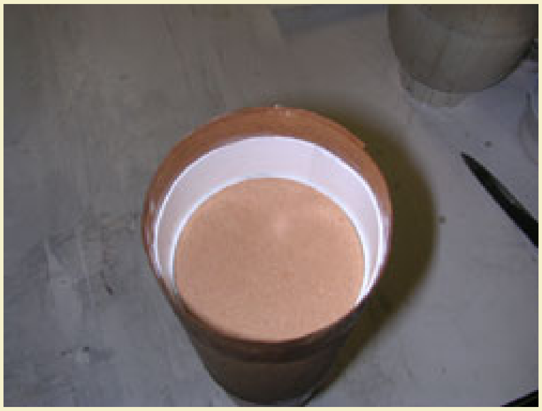


Figure 5: End disk inserted while still on the case former.

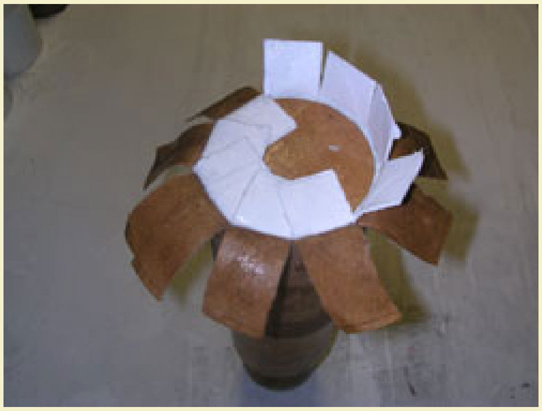
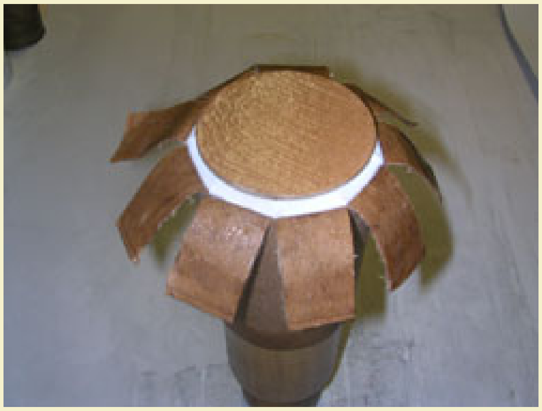


Figure 6: Pleating the first set of tabs.



hazardous failures when they blow in the gun, usually sending heavy chunks of shredded metal pipe flying through the air for substantial distances. So it is very important from a safety standpoint to produce a good quality bottom shot. The bottom shot should be well protected against gas leaks so that it can survive a shell flower-potting in the mortar without going off. A well made bottom shot should eject from the mortar if the carrier shell explodes before making it out, such that it detonates high in the air instead of in the mortar.

The most common method for making bottom shots is to use a very thick walled spiral wound tube, with a minimum wall thickness of at least 3/4" for a 3" or 4" bottom shot. The bigger the diameter gets, the thicker the case wall needs to be. When a thick enough wall can not be found, you can use multiple thin-walled tubes nested inside of each other, such that the O.D. of the inner tube equals the I.D. of the outer tube. Because such thick tubes are hard to cut, they are typically ordered precut to the desired size.

The commercial thick-walled spiral salute cores will produce a very strong and loud bottom shot. The problem, however, is often trying to obtain the desired tubes. Hobbyist suppliers typically do not carry this type of tube, so they have to be ordered in large minimum orders from industrial suppliers. Some companies that specialize in paper products for the fireworks industry will also require a BATF permit to even order these things. This often leaves the hobbyist with no choice but to roll his own bottom shots.

Using many strips of chipboard cut with the grain running in the short direction, it is possible to roll your own convolute bottom shot cores. The process of cutting all the strips and rolling them up to a thickness of 1" or more can be a tedious one, but it does produce good bottom shot cores.

The fastest method of producing good quality bottom shots I have found is the Maltese method using pasted poster board, which is the method described here. The pasted poster board is considerably stronger than chipboard, so the case thickness can be much thinner while producing the same results. Using 5 turns of poster board on a 2-1/2" case former, I have had as much as ten pounds of shell weight sitting on top of these without ever having any problems. The shots can be made louder by rolling even more layers of poster board or by spiking the shot with a denser spacing of stronger twine.

Making the Bottom Shot

Traditional Maltese bottom shots in this size usually employ four turns of poster board. Because it can be difficult to get the end tabs to lay down when they are four sheets thick, I have altered the design a bit so that the case is made from two layers-- a thick inner layer and a thinner outer layer. The tabs are formed on the outer layer, which is only two layers thick so that they can be folded down easier. The inner layer can be made as thick as you want, with loudness increasing with the more layers you use.

To roll the bottom shot casing shown in Figures 1 through 9, you will need three strips of paper. The first is a 28" long strip of poster board with a width equal to the height of the bottom shot you wish to make (3 inches in this case). This will produce about three turns around a

Figure 7: Second end disk placed over tabs.

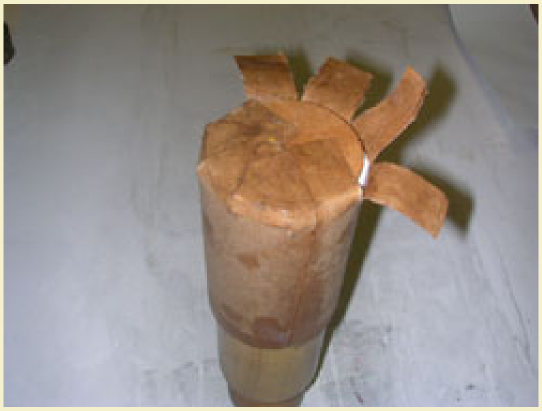


Figure 8: Pleating down the second set of tabs.

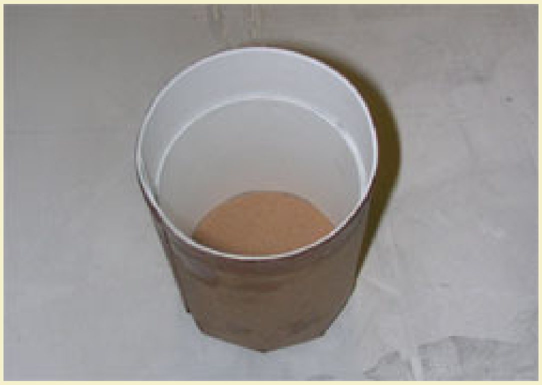


Figure 9: Dried bottom shot can ready to load.

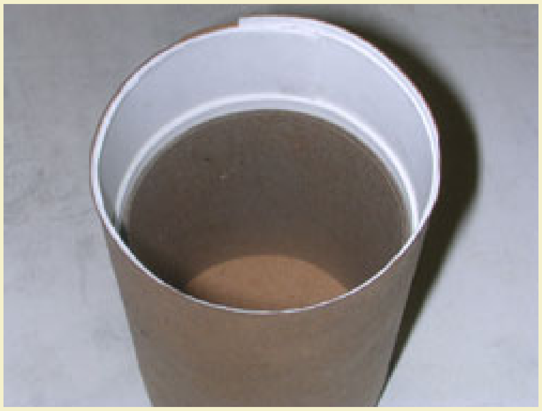


Figure 10: Chipboard liner in place.

2-1/2" case former. If you have 2-5/8" end disks available, which are somewhat common, then a better bottom shot can be constructed by rolling enough turns of the 3" wide poster board to produce a 2-5/8" diameter case on the former. This way the end disks can be supported by this inner part of the casing and the chipboard liner is not required. If you wanted to really go nuts you could use 3-1/2" disks and roll a 1/2" thick inner core, producing a larger bottom shot that would still fit inside our 5" shell.

The first turn is dry-wrapped around the case former, then the remainder of the strip is coated with paste as seen in Figure 2. The pasted strip is then quickly rolled up onto the former and any paste that oozed out onto the former is wiped up.

The second piece of paper is an 18" long strip of poster board that is two inches longer than the desired bottom shot height, or 5" wide in this case. This piece of poster board is overlaid onto a strip of 60 pound recycled kraft that is a half inch wider and of the same length, as seen in Figure 1. Both sheets are pasted fully on one side. Note that the extra half inch of kraft extends beyond the poster board on the edge facing away from the case former.

The case rolled from the first sheet is now centered on the next two sheets as seen in Figure 3, then the next two sheets are rolled up onto the case former together as seen in Figure 4.

Next you need to slide the finished case up to the edge of the case former and drop an end disk in place as seen in Figure 5. Note that the edge of the inner casing should be flush with the top of the end disk. If you are using the alternate method where the end disks are larger than the case former diameter, then the disk would actually sit on top of the inner case and it would not be visible in Figure 5.

The end of the case is closed by using a thin, sharp knife to cut tabs all the way around the circumference, which must be done quickly before the paste softens u the paper and makes it more difficult to cut. Once the tabs are cut, the kraft paper is pealed back away from the poster board, as seen in Figure 6. Paste is then brushed onto the end disk the white tabs are folded down. Paste is brushed onto the tabs as needed to get them to stick down as you go.

The second end disk placed on top of the folded tabs, pasted on top and then held down by folding over the kraft tabs as seen in Figure 8. Paste is again used as needed to help the tabs stick down.

At this point you should have a bottom shot can that looks like Figure 9. This is now set aside to completely dry before proceeding further. If the case is not allowed to fully dry before it is spiked with string, then the spiking string will lose its tension due to shrinkage that occurs to the case as it dries.

Note: a better way of building this is to insert the disks containing the time fuse first instead of the bottom disk as shown here. The reason is that it is easier to pack sawdust around the fused end before loading the flash rather than having to insert the fused end through the sawdust as seen in Figure 14.

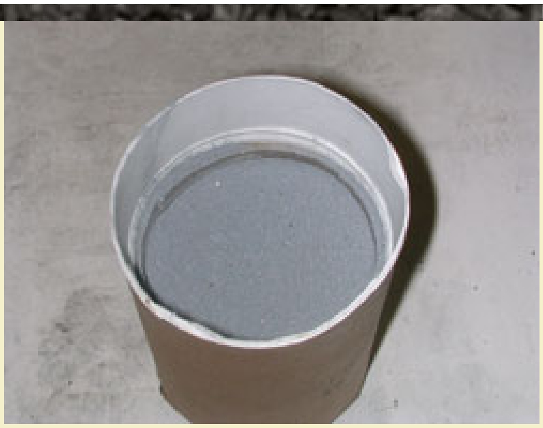


Figure 11: Filled with 70/30 flash.

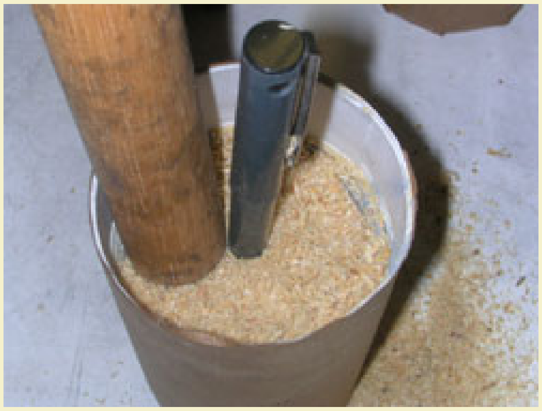


Figure 12: Tamping sawdust above the flash.

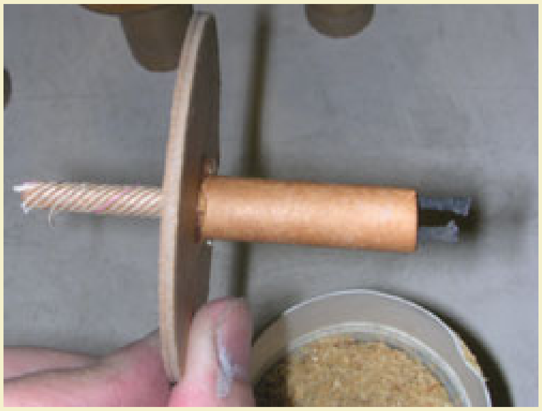


Figure 13: Fused disk ready to close the can.

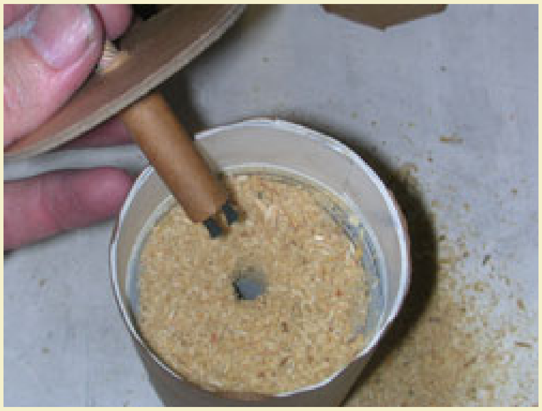


Figure 14: Care must be taken not to knock

Once the case is dry, you are ready to load. If your end disks are the same size as the case former used to roll the can, you will need to insert a chipboard liner into the case as seen in Figure 10. The purpose of this liner is to support the top disk so that it doesn't get pressed down into the easily compressible flash powder. The liner should be cut so that the top falls about 1/8" below the edge of the inner casing, which can be seen in Figure 10.

The bottom of the casing is first charged with a layer of sawdust, tamped down to a thickness of about 1/4" to 1/2". Sawdust is used both below and above the flash charge as a preventive measure against ignition from gas leaks when the container shell bursts.

Next the case is charged nearly to the top with flash powder. The flash shown here is 70 parts potassium perchlorate mixed with 30 parts American dark aluminum (also known as 809), with a handful of 10 mesh titanium flakes thrown in for spark effects. The flash was mixed by first screening the perchlorate through a 60 mesh screen to remove all the lumps. The aluminum and perchlorate were then mixed together on a sheet of newspaper by picking up the corners and shifting the pile back and forth until no more white pockets of concentrated perchlorate could be seen. The titanium flakes were then added and "diapered" in using the same technique to evenly distribute them into the mix.

No sulfur is needed for flash to take fire form a cross matched piece of time fuse. If your salutes don't ignite, the problem is your black match and not the ignitability of the flash. Adding antimony to flash is also an unnecessary increase in friction sensitivity with no discernable gain. If you want a louder bottom shot, use German dark or Indian black head aluminum, roll a thicker case or spike with more twine or stronger twine. Those are the variables that make a difference, not spiking your flash with hazardous additives.

Once filled with flash, the case is now topped off with another layer of sawdust. Because we are closing with the fused disk here, an object equal to the diameter of the piped fuse must be inserted into the center of the flash while tamping the sawdust, as seen in Figure 12. This preserves a pass-through hole for the fuse to contact the flash. Just pushing the fuse through the sawdust in hopes that it will reach the flash will result in the pipe getting plugged up with sawdust, making a fire block that will very likely prevent the salute from igniting. This added hassle is why I suggest making the can with the fused disk first so that it can be loaded upside down and closed with the bottom disk.

Figure 13 shows the fused disk used to close the bottom shot. This is the standard construction I use for all canister shells-a piece of cross matched time fuse with a dry-rolled pipe made from three turns of kraft around a 3/8" rolling rod. The pipe can also be stuffed with additional segments of black match if you are concerned about having enough fire transfer to ignite the flash. Generally a pipette is used to create an ignition point at the center of a shell rather than at one end, which results in faster flamer propagation to all parts of the shell. In the case of a flash filled salute this is really not important, but the pipe is needed to get past the sawdust barrier so it still has a function here.

any sawdust into the fuse hole.

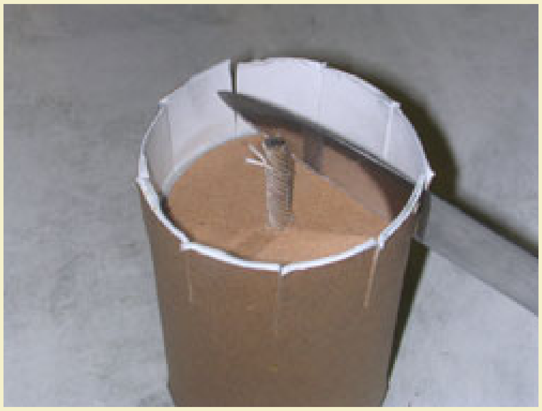


Figure 15: Slicing the tabs on the top side.

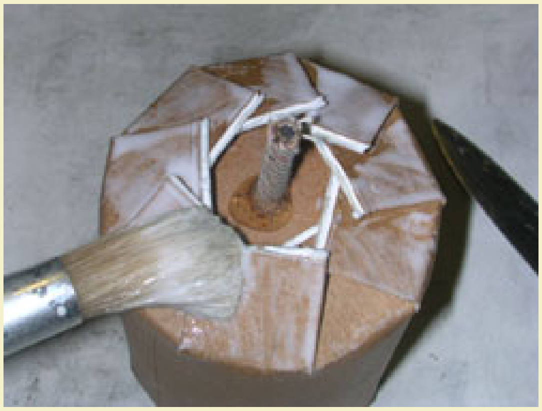


Figure 16: Painting white glue over top tabs.

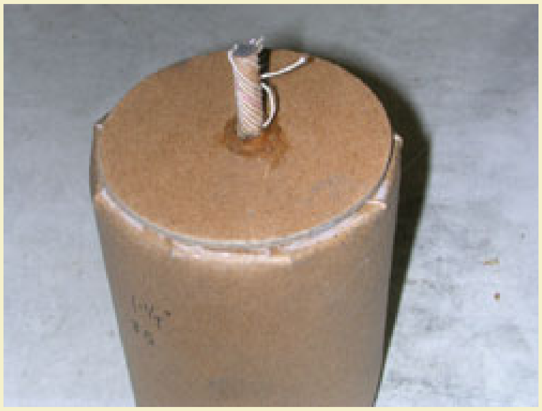


Figure 17: Hot glue sealed around time fuse base.

The shell is now closed similar to how you closed the bottom end, only this time the tabs are dry so you can not separate the kraft from the poster board. The entire tab is folded down and brushed with white glue as seen in Figure 16. A bead of hot glue is run around the base of the time fuse before inserting the top disk, then time fuse base is again sealed with another bead of hot glue once the top disk is in place.

Since bottom shots don't have stars and burst symmetry is not a concern, you can spike them with cotton twine if you choose. When using cotton twine, saturating the twine either before or after it has been applied will go a long way toward increasing its holding strength. I prefer to use the most absolute strongest twine I can find, which happens to be the imported 8 strand linen flax twine sold by Pyrosupplies.com. You can never have too much spiking twine wrapped around a bottom shot, so consider Figure 18 to be somewhat of a minimum. The more you use, the louder it will be.

The bottom shot is completed with a paste wrap of 2 turns 30 pound recycled kraft paper. The recycled kraft is preferable to virgin kraft when pasting in shell inserts, as it lays flatter, shrinks tighter and thus produces a better gas-tight seal. Be sure that the paste wrap surrounds and makes a cone around the base of the time fuse, which is the most leak-prone area.

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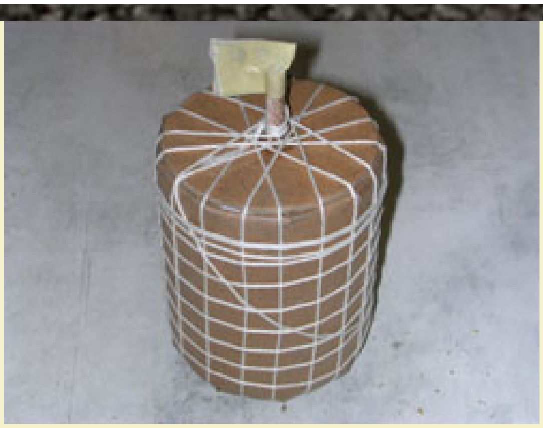

Figure 18: Spiked with 8 ply linen twine.

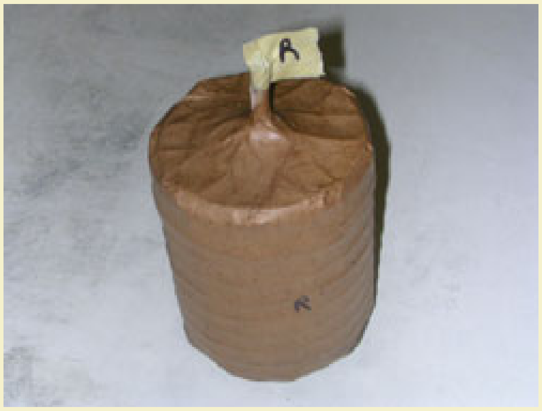

Figure 19: Pasted bottom shot is dried and ready for cross matching.

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5" Rondelle w/Bottom Shot...

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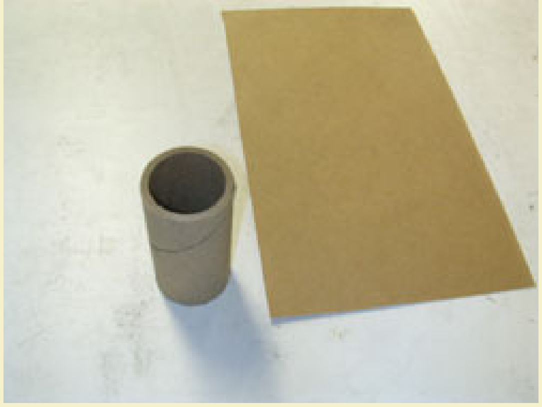


Figure 20: Salute core with outer wrap.

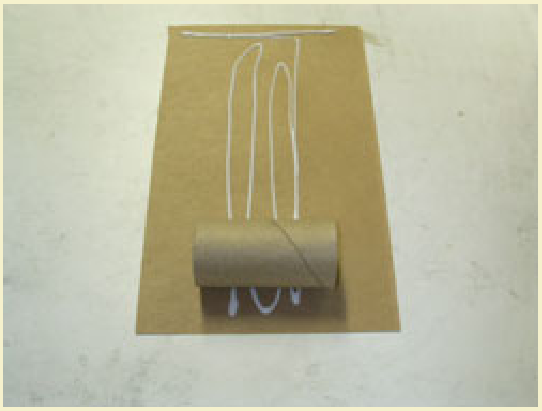


Figure 21: Rolling the outer wrap.

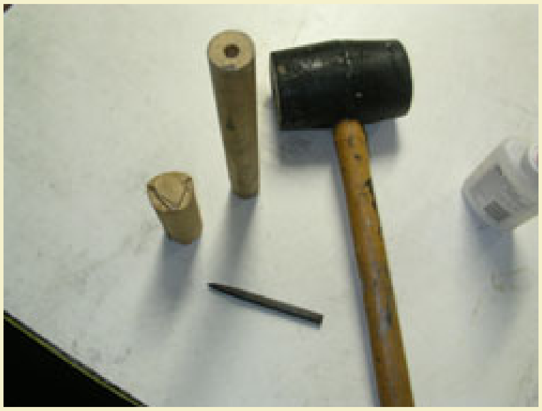


Figure 22: Tools for punching the fuse hole.

Making Timed Salutes

There are various ways to make small salutes for use in canister shells. The method shown here is about as simple as you can get without resorting to plastic insert shells. Basically all you do is roll two turns of 70 lb kraft around a thick inner tube and tri-fold the ends shut like when making pupadelle shells.

The core used for these salutes should be pretty thick in order to get a nice loud report. The ones used here have a 1/8" thick wall, which is about the minimum you would want. The tube measures 2-1/2" long with a 1" I.D. and 1-1/4" O.D. This is the biggest diameter tube you can use while still being able to fit seven of the completed salutes into the shell. You can use a bigger core of course, but then you will only have six reports in your ring. You can also roll your own cores from chipboard or even pasted poster board if you wanted, with the latter giving the strongest casing.

Figure 21 shows two turns of 70 lb kraft being rolled onto the core. The glue running the length of the paper is not really necessary, I just use it to help keep the core from sliding around when folding over the ends.

Figures 28 through 30 show how to make the tri-fold over the end of the tube, in case you don't already know how to do this common fold by now. I prefer to apply white glue between the folds so that the resulting end cap is hard and stays flat after it dries.

Some builders will argue that you can't get good timing on shell inserts without using hand rammed spolettes. However, it has been the experience of myself and others that very good timing can be obtained from standard Chinese time fuse as long as you accurately control the spacing between the cross-match points and use a good quality black match to cross-match the fuse with. Spolettes are both time consuming to make and unwieldy to install in small reports such as these, so time fuse is the logical choice.

The time fuse can be installed either through the side of the report or through one of the ends. I prefer installing the fuse in the end because you don't have to actually drill through the casing to do it, it allows packing sawdust around the fuse inside the casing and it makes spiking and pasting the reports easier. The only time side fusing is really needed is when you have to stack several rows of salutes on top of each other and you want to keep the shell height to a minimum.

In order to punch the time fuse hole through the triangle fold, you

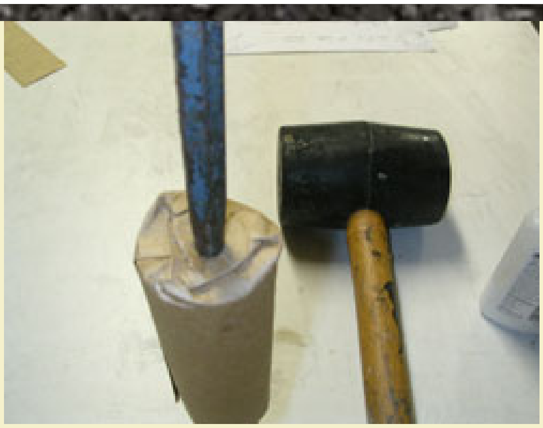


Figure 23: Punching the fuse hole.

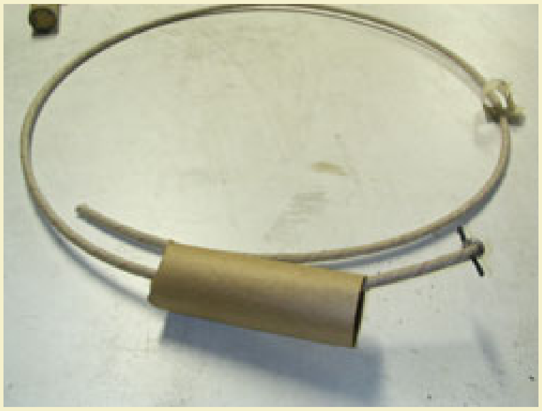


Figure 24: Thread case onto time fuse coil before cross-matching.

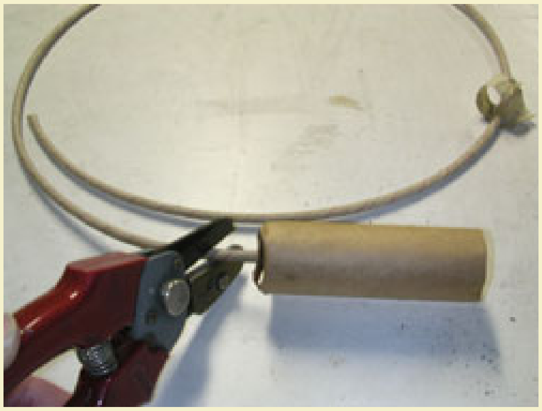
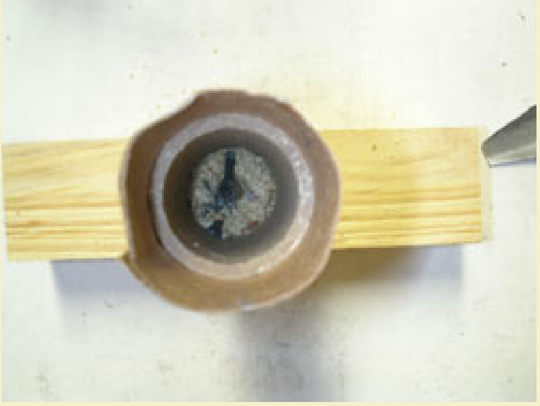


Figure 25: Cutting time fuse to proper size.



need to make a special dowel rod that has a 5/16" hold drilled through one end, as seen in Figure 22. The dowel rod should equal the I.D. of your salute core, which is 1" in this case. The case is slipped onto the rod and a metal center punch is hit with a rubber mallet to punch the hole, as seen in Figure 23.

Next a long length of time fuse is threaded through the hole and cross matched after pulling it through, which will look like Figure 24. At this point you will need to mark the point where the second cross-match hole will be punched later. The timing will be different on each report, and the lengths will vary depending on how fast you want your rondelle to progress. The timings I used for this shell are shown in the table below. I find that faster paced progressions make the circular motion more noticeable.

Time Fuse Lengths

Component	Timing Length
Main Shell	1-1/4"
Report #1	3/4"
Report #2	7/8"
Report #3	1"
Report #4	1-1/8"
Report #5	1-1/4"
Report #6	1-3/8"
Report #7	1-1/2"
Bottom Shot	2"

After marking the time fuse, it is pulled back through the case until the cross match prevents it from pulling any further. The fuse is then clipped off 1/4" above the punch mark you previously made. Anvil cutters are used for this task in order to prevent the sheering action that scissor type cutters would produce (Figure 25). It is more efficient to prepare all seven reports up to this point before loading them. Be sure to mark each time fuse with a number indicating when it is to fire in the sequence (ie- 1, 2, 3). This is best done by folding a piece of masking tape over the end and writing the number on it.

Once the reports are fused, the next step is to ram some sawdust in around the time fuse, as seen in Figure 26. This precautionary measure produces an additional barrier to gas leaks that can occur when the container shell bursts. If even one salute detonates when the shell bursts, it will set off all other salutes including the bottom shot, resulting in one large detonation that destroys everything in the shell. So any extra work that helps keep this from happening is worth the extra time it may take.

The salute is charged to the top of the core with flash and then topped off with sawdust once again, similar to how the bottom shot was constructed. The salute is closed with another tri-fold as seen in Figure 28 through 30.

The salutes are then spiked with the strongest twine you can find (once again the PyroSupplies 8 ply linen twine was used here). Start by running a bead of hot melt glue around the base of the time fuse. When the glue sets a little, start by tying off on the time fuse with a clove hitch, then run at least six verticals and eight horizontal wraps as seen in Figure 31. As with the bottom shot, the more spiking you use the louder it will be. However, too much spiking may make the salutes oversized so that you can't fit all seven of them in your shell, so you will need to do some trial and error based on the thickness of your string and the diameter of your salute cores.

After the salutes are spiked, they are finished with a paste wrap of two turns of recycled 30 lb kraft paper. Be sure to pile the paper up around the base of the time fuse to help prevent gas leaks in this vulnerable area.

Loading the Bottom Shot

There are two several methods for building a shell with a bottom shot. One traditional method involves making the bottom shot O.D. equal to end disk diameter of the shell being built, such as 4-1/2" for a 5" shell. The shell casing is then rolled around the completed bottom shot instead of using a case former, which locks the bottom shot good and tight into the bottom of the shell casing. There is no need to use sawdust or sand to pack around the bottom shot since it is built right into the shell.

The advantage to rolling the shell casing around the bottom shot is faster construction time. So if you had many shells to make, then this would be the method to use. However, there are several disadvantages to using this method which make it unattractive for most hobbyist applications. For one thing, it forces you to use a bottom shot equal to the shell diameter, which can be quite larger than you may wish to use in many cases. I personally can not hear the difference between a 4" bottom shot and a 5" one, so why waste the extra flash powder unless you gain something from it? In the case of some competition rules such as those used by PGI, using this method of bottom shot construction would result in bottom shots that are too large to be permitted by the size restrictions for certain categories. You have no choice but to make the bottom shot diameter equal to the shell diameter, there is no flexibility with this method.

Another problem with using this method is that the completed shell has a larger diameter than it should, since the bottom shot will have a larger diameter than the standard case former of the same size. In many cases this added size is enough to cause problems with the shell fitting into the mortar, especially HDPE mortars. Often the shell must be pushed into the mortar, leaving no blow-by clearance and thus subjecting the shell to more pressure than it or the mortar may be able to withstand when fired. If building multi-break shells, this oversized bottom break will also not align flush with the other breaks which are rolled on a standard size case former. This results in a seam that is not flush between the last break and the rest of the shell, which will in turn leave a big air gap at the seam when you paste in the shell.

More...

Figure 26: Tamping sawdust around time fuse.

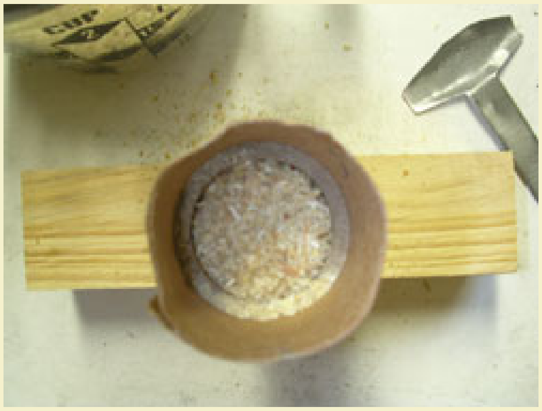


Figure 27: Sawdust pressed above flash charge.

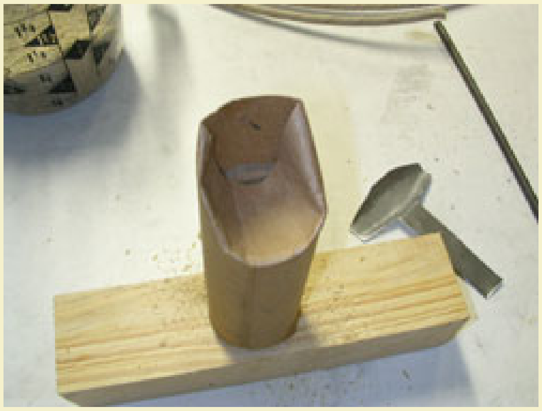


Figure 28: First fold of triangle fold.

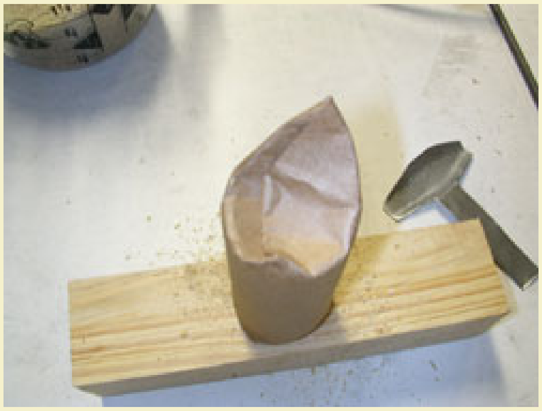


Figure 29: Second fold of triangle fold.

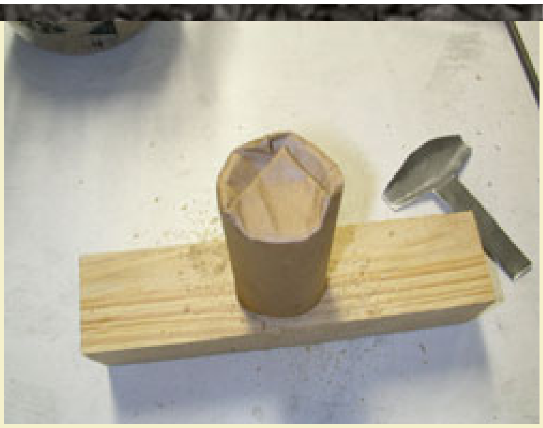


Figure 30: Completed third fold of triangle fold.

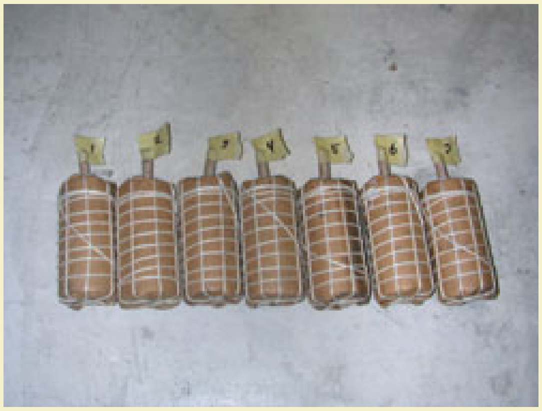


Figure 31: All salutes spiked and numbered.

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5" Rondelle w/Bottom Shot...

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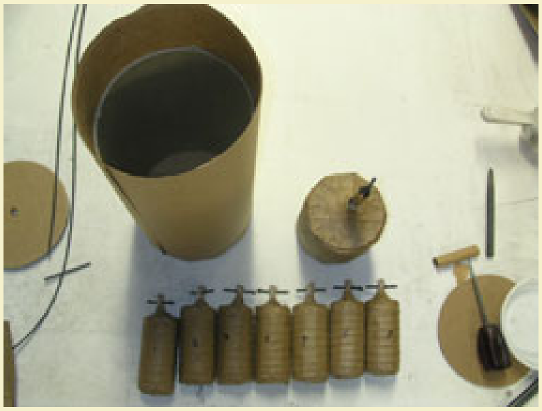

Figure 32: Shell case with components ready to load. Note the sequence numbers have been written on the reports.

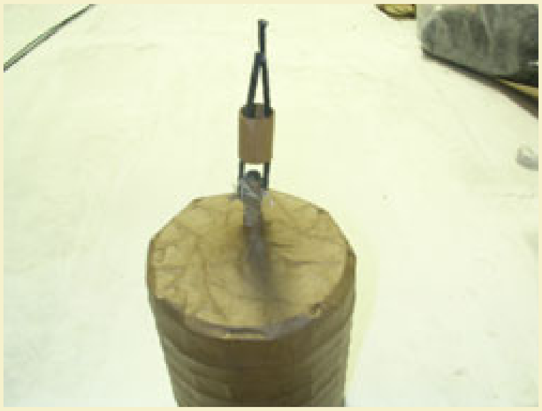

Figure 33: Retainer sleeve on the long cross-match of the bottom shot.

There is a way to fix the above mentioned problem if you really want to use this method for building multi-break shells with a bottom shot. You must produce a bottom shot using an undersized case former with undersized end disks so that the completed bottom shot will have an outside diameter equal to the standard case former size for the shell being built. So for our 5" shell example, you would need about a 4-3/8" case former with matching disks, both of which you would likely have to make yourself. Then of course you would have to have a similar set of undersized formers and disks for each size of shell you intend to build using this method.

Another way to get around the size problem is to build the bottom shot the next size down from your shell, such as a 4" bottom shot for a 5" shell, and then roll chipboard or newspaper around the bottom shot until it is 4-1/2" in diameter. Once built up to the correct O.D., you can then roll the shell casing on it. This is a hybrid approach that is sort of a cross between rolling directly on the bottom shot and dusting it into the bottom of a case rolled on a case former. It becomes troublesome when the difference between the bottom shot diameter and the shell diameter are more than an inch however.

The method of construction used for this project is known as "dusting in" the bottom shot. With this method, the case is rolled on a former as usual and a bottom shot that is smaller than the shell diameter is placed into the bottom and packed in with sawdust, as seen in Figure 34.

The bottom shot is first cross matched with an extra long piece of black match, thus increasing its probability of taking fire. A small section of match pipe can be cut and used as a sleeve to keep the long strands out of the way when loading the shell, as seen in Figure 33.

Once the case is rolled and the end disk pleated into place, two turns of chipboard measuring 7-1/2" tall are inserted into the case. The bottom shot is first loaded down into the bottom of the case so that it is centered, then sawdust is poured around it and tamped down with a long dowel rod as seen in Figure 34. The sawdust will compress a considerable amount, so it takes several fills before it reaches the top of the bottom shot.

Loading the Shell

Once the bottom shot is tightly dusted into the shell, it is covered with a thin layer of rough powder, as seen in Figure 35. This will give you a solid, level bedding on which the timed reports are loaded onto. The reports shown in this project were very tight fitting, and all seven

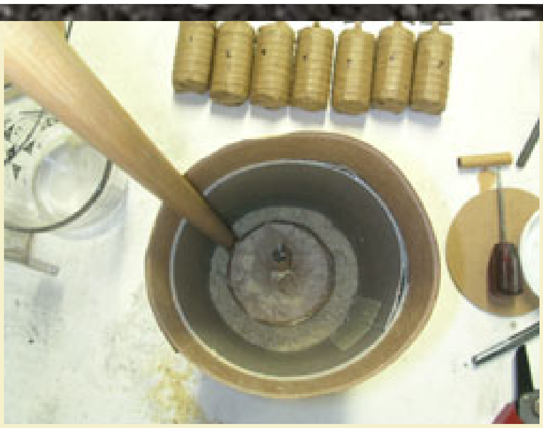
Figure 34: Tamping sawdust tightly around the bottom shot.

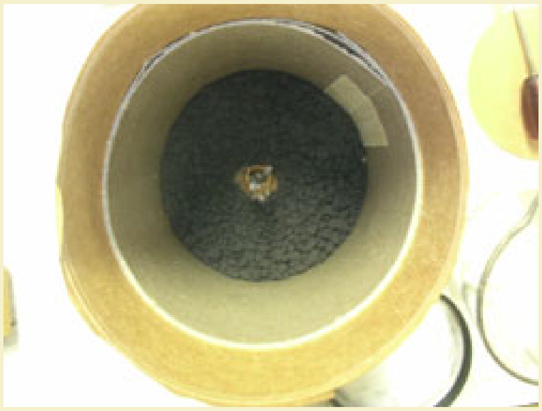
Figure 35: Covering the top of the bottom shot with rough powder.

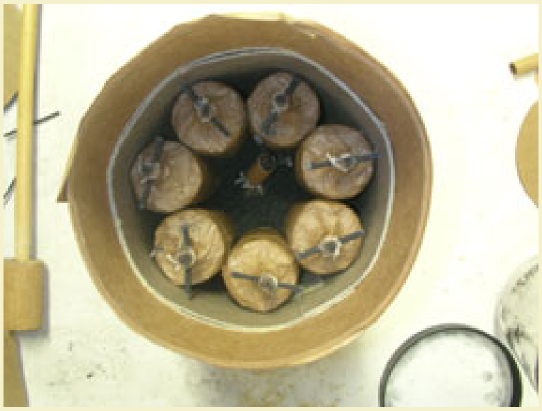
Figure 36: Reports loaded tightly in to a ring.

of them just barely fit into the shell. Because the reports fit so tightly, there was no need to dust them in. The only purpose of ramming sawdust between the reports and the shell wall is to lock them into a solid ring. If the 7th report requires quite a bit of effort to cram into the shell, they will be tight enough to produce a good break without the need for sawdust. Otherwise you will need to tightly tamp sawdust between the reports if they sit loosely in the shell.

Important: since you went through all the trouble of correctly numbering the reports in the sequence that they will fire, be SURE to load them into the shell in the correct order. Line them up on your table in numerical order and insert them one after the other in a clockwise progression. If you get even just one of them in the wrong place, you no longer will have a rondelle.

The empty space behind the reports was filled with 1/8" rough powder, which is ball milled meal powder pushed through a 1/8" screen as described here. Because ball milled meal powder made with a good charcoal like willow or spruce is quite strong, I chose to fill the central break cavity with the 1/8" rough powder as well. If your own rough powder doesn't have enough kick, you will want to fill the central break cavity with commercial or home made 3FA black powder.

Once the break charge is loaded level with the top of the reports, the remaining space is filled with standard 1/4" rough powder, as seen in Figure 38. An end disk with the time fuse and pipette hot glued in place is pushed through the rough powder to close the shell. It helps to bounce the shell on a table while working the piped time fuse down into it, otherwise it is difficult to get the disk to seat all the way down onto the chipboard liner.

Completing the Shell

The remainder of this article is a review of good canister shell building practices for those who haven't read the 4" Color Break introduction to canister shell building. For those who already know how to finish the job, you get to leave class early.

Now, there is a quick-n-dirty school of thought that finds it satisfactory to simply fold the overhanging paper down onto the disk all at once, slap the second disk on and call it a day. No pleating, no white glue- just crumpled down and held with four strips of masking tape if not spiked right away. Why is this bad? Because what goes together easily also comes apart easily, and closing a shell like this will create a very weak containment of forces pushing against both ends of the disk. When a properly built canister shell breaks, both end disks should remain intact, with the paper still sandwiched between them but sheared clean off around the edges. When slapping a shell together using this slop method, your chances of getting a hose break greatly increase, and is almost guaranteed if you are using cotton twine to spike the shell with.

Sometimes a hose break looks like a nice break if you are looking at it from the right perspective, which is why some people are fooled into thinking this method works. Having inspected the fallen remains of many shells built like this, I can assure you that it doesn't. The only way you can really get away with slop construction is to break the

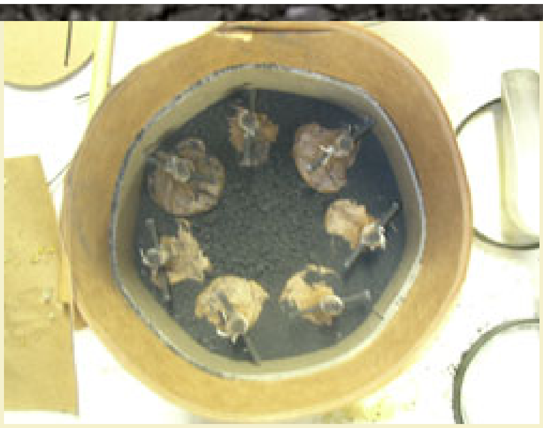

Figure 37: Filling all open spaces with fast burning 1/8" rough powder.

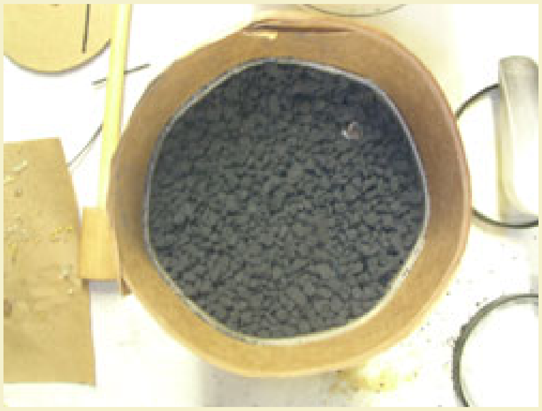

Figure 38: Leveling the space above the reports with 1/4" rough powder.

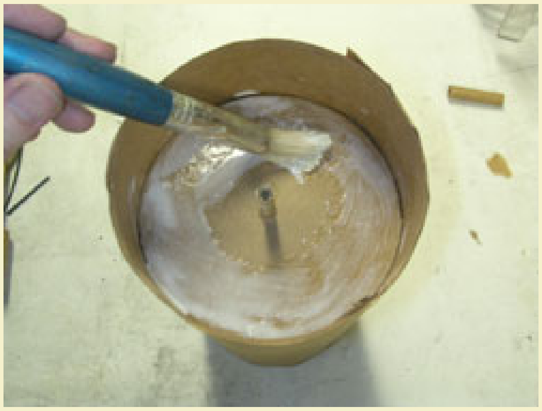

Figure 39: Using white glue when pleating over the end disk.

shell hard with a flash bag or whistle mix booster, which we are not doing here. While a dense color break can hide defective burst patterns depending on burst orientation, a ring of inserts such as the shell built here is much more revealing. It is important that a rondelle shell produce a very clean ring, thus it is important not to cut corners when building this shell.

After closing with the time fuse disk, glue is applied to the top of the disk as seen in Figure 39. Each layer of paper is then pleated down in the pattern shown in Figure 40, with a new application of glue applied between each layer. Not only does this result in a much cleaner and tighter compression of the paper between the two disks, it insures that the paper can not pull out and allow the disks and shell contents to be jettisoned form the end like a sky mine.

Before applying the second disk, a bead of hot glue is run around the base of the time fuse. It is important to apply white glue to the top and apply the second disk quickly before the hot glue dries (Figure 41), otherwise the dried glue can prevent the disk from seating all the way down. The purpose of this glue is to provide a secondary fire block in case some lift gases make it past the outer seal. It's a very unlikely scenario, but then so is a piece of foam debris taking out the space shuttle. The idea is to take every precaution.

The shell is now spiked with 18 verticals of high quality flax twine. Do not be tempted to use cotton twine. I know it's cheap, I know it's easy to find and I know it's worthless for spiking a shell if you want good break symmetry. The twine used here is the "Domestic Six Strand Natural Flax Twine" sold by pyrosupplies.com, which is the perfect strength for 5" canister shells. The vertical spiking is only a few turns where the bottom shot is located, then about five turns around the area where the salutes are.

Finally for pasting in the shell you want 4 or 5 turns of a good 60 to 70 pound virgin kraft paper. Figure 43 shows the tan color typical of a high quality paper once it has been saturated with paste. A good kraft paper will not tear easily even when it is wet, which is nice except for when it comes time to tear the overhanging paper to pleat the ends, as seen in Figure 44. While you can use scissors to cut the tabs, tearing the paper by hand actually results in feathered edges that lay down better. Both ways will work, but tearing has the slight advantage for producing the most gas-tight seal possible.

If you can not seem to get the tabs to tear in a straight line, then chances are that you rolled the paper with the grain in the wrong direction. Paper tears easiest with the grain, and the grain should be running from end to end of your shell.

Some builders will fold the tabs over as-is without separating them, while others will separate them out and lay them down for each layer of paper. The latter method results in the best prevention of gas leaks, since folding them all at once can result in wrinkles or pockets of air that lead directly to the shell inside. A good compromise between quality and speed of construction is to separate the tabs into two layers, folding half of them down the first time around (Figure 45) and then folding the rest the second time around.

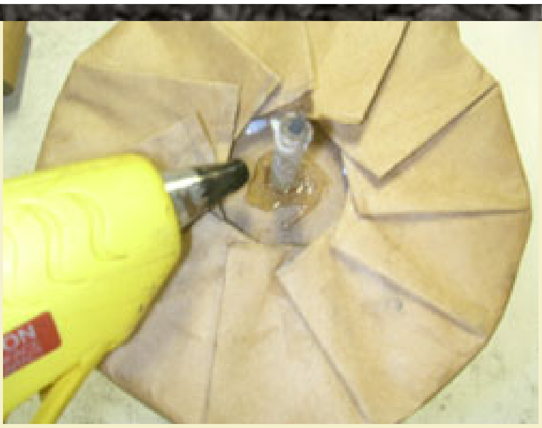

Figure 40: Sealing around the time fuse with hot glue.

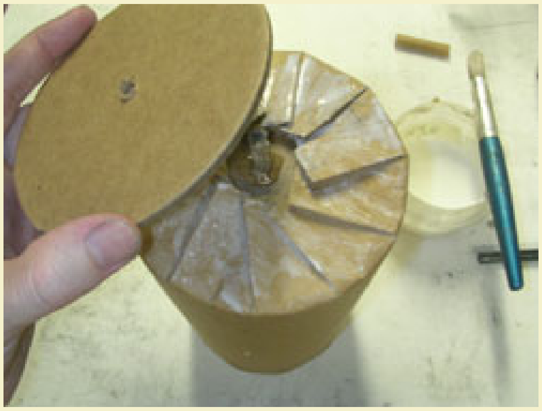

Figure 41: Applying the second end disk.

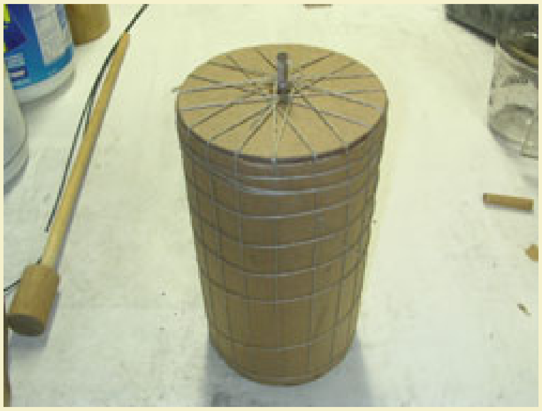

Figure 42: Spiked with high quality flax twine.

To avoid an overly large hump of paper at the center of the shell, I'll sometimes tear some paper off the ends of the tabs to make them shorter, as seen in Figure 45. A trick to avoid having to do this is to use progressively shorter strips of paper when rolling the casing, as seen in Figure 43. The first strip is the full length required to cover both ends. The width of the second strip is about an inch less than the first, then the width of the third strip is two inches less than the first. This way the tabs get shorter and shorter the farther from the inside you get, resulting in less pileup in the middle and thus less time required for all the pasted paper to completely dry out.

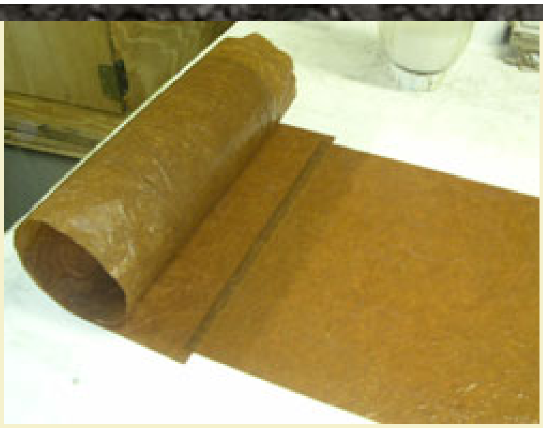

Figure 43: Pasting in with 4 or 5 turns of 70 lb virgin kraft.

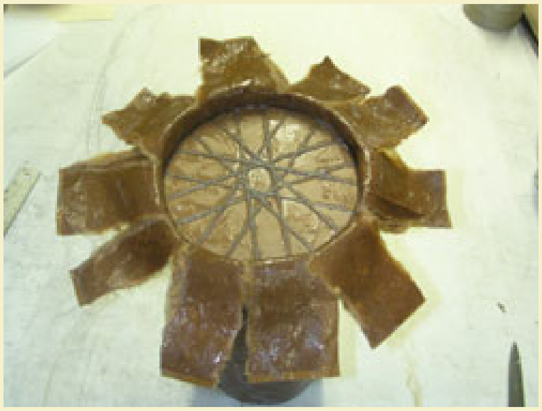

Figure 44: Tearing the tabs by hand.

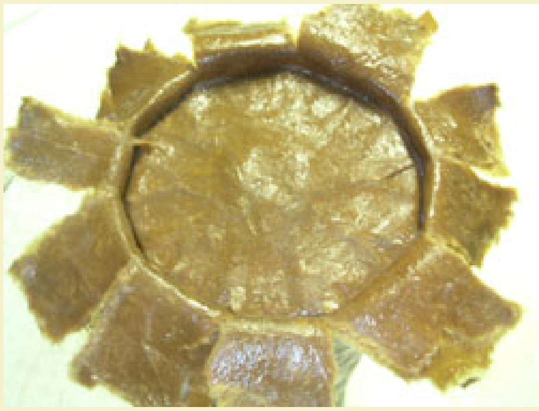

Figure 45: Folding the tabs down in two separate layers.

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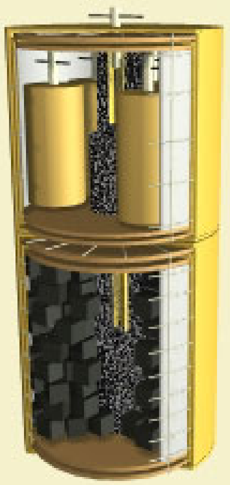
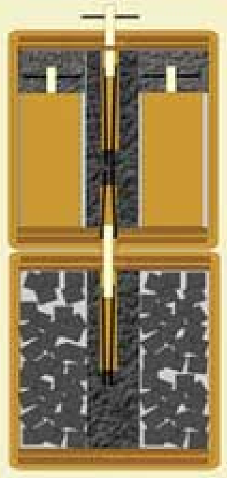
Volume 2, Issue 6

Build This...

5" Sun and Planets Shell





June, 2002 Issue

Build This:
5" Sun and Planets Shell

Design Notes:
Maltese Multi-break Shells

Tool Tip:
Build a Maltese Shell Rolling Tool

Technique:
Making Dragon Egg Microstars

Summary:
This shell is a variation of a "shell of shells" effect, where a single shell bursts into a ring of smaller shells which all break in a ring of small color splashes. The Sun and Planets effect is characterized by the simultaneous break of all the planets and a larger central color break (the sun). With precise timing and well made insert shells, this effect can be quite attractive in the sky.

Prerequisite: Insert Shells, 5" Comet Shell

Materials:

BREAK 1 (planets)

- (2) 4-1/2" dia end disks with 7/32" hole
- (2) 4-1/2" dia end disks with 1/2" hole
- (3) 7" x 24" long 70lb kraft strips, grain short
- (1) 4" x 14-1/2" long chipboard, grain short
- (7) 1-1/2" I.D. insert shells w/1" between cross match
- (1) piece of chinese time fuse w/1-1/4" between cross match
- (1) 3/8" ID x 2" long pipette
- (1) 5" piece of cross match
- (1) 1" piece of cross match

BREAK 2 (sun):

- (2) 4-1/2" dia end disks with 7/32" hole
- (2) 4-1/2" dia end disks with no hole
- (3) 8" x 24" long 70lb kraft strips, grain short
- (1) 5" x 29" long chipboard, grain short
- (1) piece of chinese time fuse w/1" between cross match
- (1) 3/8" ID x 2-1/2" long pipette
- (1) 3/8" ID x 1-1/2" long pipette
- (1) 6" piece of cross match

Tools:

- 4-1/2" dia. case former
- Rubber mallet
- 1-5/8" OD canulle (solid or hollow pipe)
- Cross match punch
- 7/32" and 1/2" drill bits
- Hot glue gun
- Scissors

- (1) 4" piece of cross match

Unmeasured Materials:

1/2" cut or round stars, strong twine that doesn't stretch, 2FA black powder, rough powder, sawdust, white glue, masking tape, tissue paper and wheat paste.

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5" Sun and Planets Shell...

Page 2

Introduction:

The sun and planets shell is a classic Italian design that, while seldom seen in public shows, is a favorite among armature builders. The design is a variation of the shell of shells type effect, whereby a single shell breaks into a ring of smaller shells to create a circle of small breaks in the sky.

The key distinction between a sun and planets shell and a normal shell of shells is that the sun and planet shell begins with a dark break that throws the planet shells out in a ring and allows them to get far enough away so that when they break they will not overlap the larger color break of the "sun," which is the second break.

Figures 1 through 3 show some of the effects possible with the sun and planets shell. Figure 1 is suspected to be a regular shell of shells, since the center break appears to have broke first and is fading out as the planets break. Figures 2 and 3 show that the sun and planets all broke at the same time.

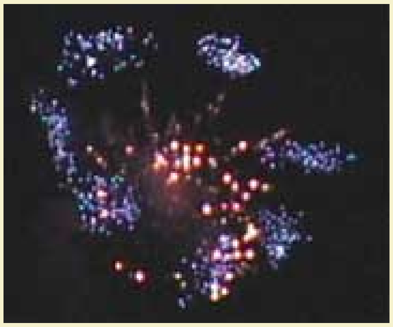
Figure 1: Blue planets with red sun.

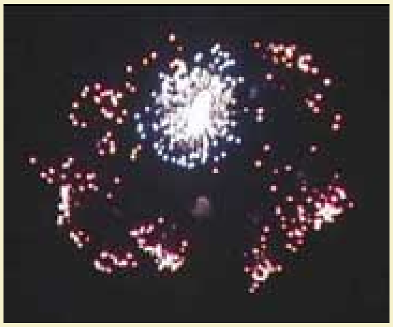
Figure 2: Red planets with blue sun.

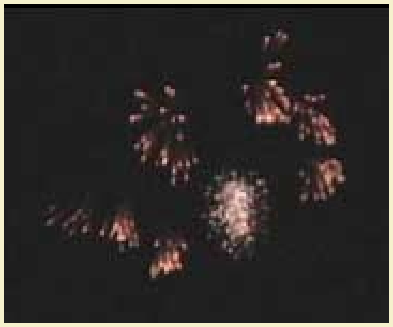
Figure 3: Willow planets with firefly sun.

Methods of Construction:

There are a few different ways to achieve the sun and planets effect. Figure 3 shows the simplest method, which is really a shell of shells and not a sun and planets shell, but the effect is similar. The insert shells and the color break are all loaded into the same break, making it a single break shell. The insert shells are thrown out at the same time the color break opens, thus there is a delay before the planets are seen. This method does not allow the shells to clear the span of the color break the way the two break method does.

Figure 4 is also technically a shell of shells, even though the inserts and color break have been packaged into two separate breaks. There is no time fuse between the breaks, only an empty tube that allows the fire to pass through and break both shells at once. Hence, there is only one detectable break in the sky, making this a single break method. The purpose of separating the inserts and stars into two separate breaks is to both increase the integrity of the shell and improve the symmetry of the color break. Analysis of shell breaks using video has revealed that putting the stars and the inserts into one long break can create a flat spot in the color break when seen from a side view. Longer compartments within shells are also more susceptible to side split and flower potting during lift than are shorter compartments.

Figure 5 shows the technically correct method of making a true sun and planets shell. The shell is a two break shell in which the first break is the planets. The time fuse on the second break is identical in timing to the time fuses on each insert break. This way the sun will break at exactly the same time as the planets. Note that the planet break can be opened while the shell is still ascending and the relative velocity of all the planets will still keep themselves aligned around the second sun break as they all rise together.

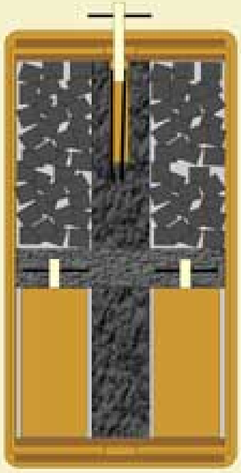
Figure 3: The single break method.

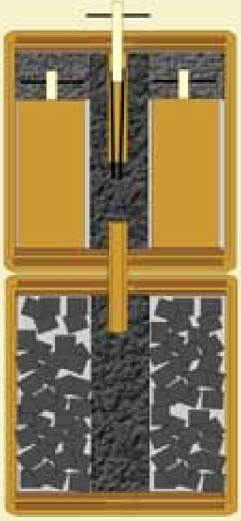
Figure 4: The single break compartmentalized method.

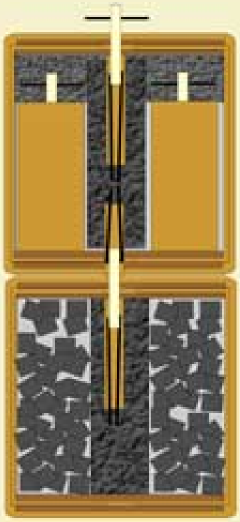
Figure 5: The two break method.

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5" Sun and Planets Shell...

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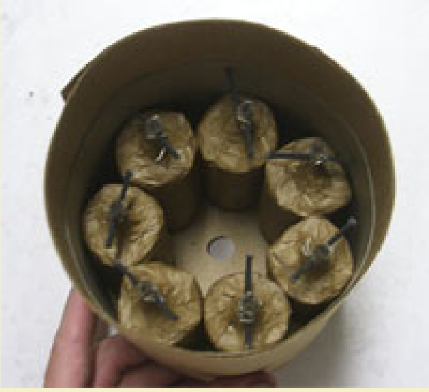
Figure 7: Seven insert shells arranged in a ring.

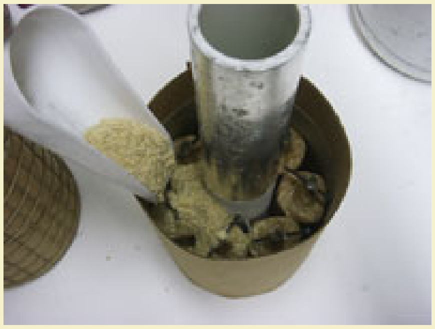
Figure 8: Packing sawdust into the gaps between the shell wall and canulle.

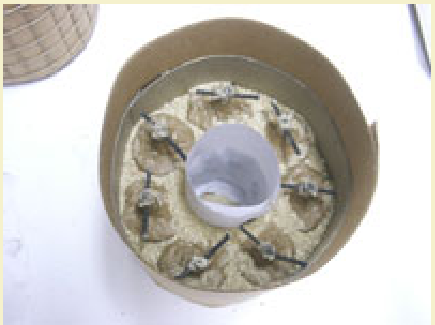
Figure 9: Sawdust fully loaded and canulle is removed.

Constructing the Planet Break:
First prepare two 4-1/2" diameter end disks by drilling a 1/2" hole in the center. These will both be used for the bottom disks of the first break, which holds seven 1-1/2" insert shells. Since this is a multi-break shell, the hole in the bottom of the shell will allow the time fuse from the second break to enter into the first break.

Begin by rolling three sheets of 24" long by 7" wide kraft around the case former. One trick that makes it easier to slide the case off the former is to roll the sheets with a few inches overhanging the edge. This gives you something to grab onto when adjusting the case for placement of the end disk. Adjust the case so that 1-1/2" of paper extends beyond the end of the former and insert one of the disks with the 1/2" hole onto the end of the former. Proceed to pleat the paper over the disk, one layer at a time with white glue between each layer. Taking shortcuts here and just pleating all the layers down together can result in end plugs blowing out, risking a poor break.

Slide the case off the former and insert a single turn of chipboard measuring 4" wide by 14-1/2" long. Normally two turns of chipboard is used when building canister shells, but in this case the extra turn would prevent all seven insert shells from fitting inside. With one turn of chip, the inserts will fit very snugly with no need to shim between them.

Before loading the inserts, stick a piece of masking tape over the hole from either the inside or outside of the bottom disk. This is to prevent the break charge from leaking out until the two breaks are ready to be stuck together. Some builders will build the last break first and then place the unloaded first break on top of it during loading. I find that it is easier to fully load all breaks and then spike them together afterwards, especially where three or more breaks are required.

Figure 7 shows all the inserts loaded into the shell. Normally I find it easier to load canister shells upside down so that the time fuse is at the bottom of the can while it is being loaded, but this particular break requires that it be loaded from the bottom up. This is because the insert shells must sit firmly on the bottom of the shell with their time fuses pointed away from the lift charge. If the insert shells were oriented upside down, then setback forces from firing the shell could break the seal around the time fuses where they enter the inserts.

The 1-5/8" diameter canulle is wrapped with two turns of tissue and inserted into the core between the inserts, as seen in Figure 8. Sawdust is now packed between all the gaps around the inserts using a small rod to tamp it down. This sawdust helps hold the inserts in place and improves the symmetry of the break. Once the sawdust is packed level to the tops of the

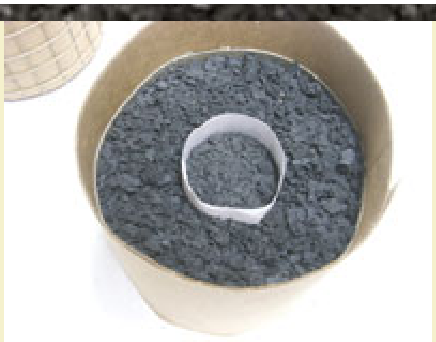

Figure 10: 2FA is loaded into burst core, while rough powder is used to fill the remaining space above the insert shells.

inserts, the canulle is removed as shown in Figure 9.

The central burst cavity is now filled with 2FA until level with the top of the chipboard. The remainder of the space above the inserts is filled with rough powder until also level with the chipboard, as seen in Figure 10.

An end disk prepared with a time fuse measuring 1-1/2" between cross match holes is now used to close the shell. Go here for details on how to prepare the time fuse. The pipette used in this break will be 2" long, directing fire to the center of the shell as required for an optimized flame progression through the burst charge. It will be necessary to bounce the shell on the table in order to settle the time fuse into the 2FA core, especially if you are using unglazed homemade 2FA. The remaining paper is now pleated over the disk as before and a second end disk is glued on each end of the shell (note that the second bottom disk must also have the 1/2" hole).

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5" Sun and Planets Shell...

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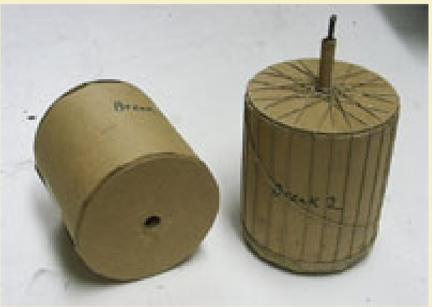

Figure 11: The second break is vertically spiked before attaching the first break.

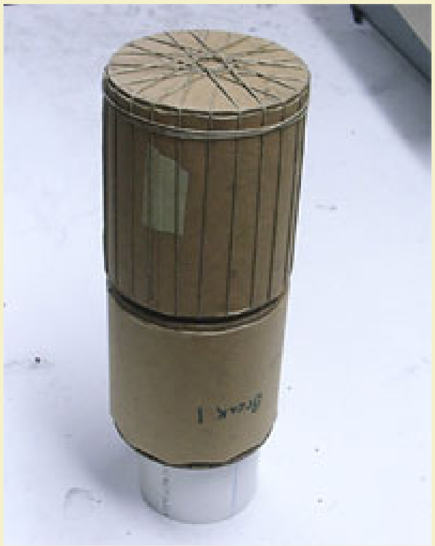

Figure 12: The second break is inserted upside down into the hole in the bottom of the first break.

Assembly and Spiking:

The second break is a standard five inch color break that measures five inches in height (see materials list under Break 2 for other dimensions). The time fuse for this break is the same as the time fuses used on the insert shells in the first break (1" between cross match holes in this case).

After loading and closing the second break, a four inch piece of cross match is inserted into the time fuse, then a 1-1/2" long sleeve is glued around it in the same way that pipettes inside the shell are created. This pipe is made with 3 turns of 70lb kraft around a 3/8" former. The purpose of this tube is to provide a rigid sleeve around the time fuse so that it can be easily inserted into the bottom of the first break. The cross match should extend beyond the top of the pipe to help insure ignition.

The second break is now spiked in the vertical direction only, preferably using the offset method to help keep the string flat on top so the two breaks will not have a pile of string between them. Figure 11 shows the two breaks ready to be attached.

Puncture the piece of tape over the passfire hole on the bottom of the first break and invert the shell onto a fixture that protects the time fuse, as seen in Figure 12. The second break is now inserted into the first break, which may require some bouncing on the table to get the time fuse pipe to settle into the break charge.

The two shells are now bound together by vertically spiking the first break onto the second break, as seen in Figure 13. This may seem a little tricky at first, since it is important to keep the two breaks pressed firmly together while applying the first several loops of twine. The twine should be applied as tight as possible so that there is very little space between the two breaks. If the first couple passes of twine are not applied tight enough in the beginning, then the later loops of twine will pull the shells closer together and cause the first few strands to become loose.

Once all the vertical spiking is applied, the twine is run down to the bottom of the shell to begin the horizontal spiking. The spacing of the horizontal spiking on the bottom break is close together as for a normal shell. The general rule for spiking is that the squares created by the crossing twine should be about the same size as the stars you are using.

Once the bottom break is fully spiked, the twine is tightly wrapped several times around the shell at the point where both breaks come together. The twine should completely cover the area between the two breaks, which helps to fireproof the gap and also pulls the vertical spiking tighter. See Figure 14 for the full spiking pattern required for the shell. Note that the spiking is much wider on the top break, due to the fact that it contains insert shells instead of stars.

With the spiking complete, the shell is pasted in with three 24" long strips of 70lb kraft. The width of the strips can be determined by using a thin strip of paper as a tape measure to gauge the distance from the base of the time fuse, down the side of the shell and then slightly past the center point on the bottom of the shell. For more information about pasting in canister shells, go here.

The shell is finally lifted and leadered as explained here.

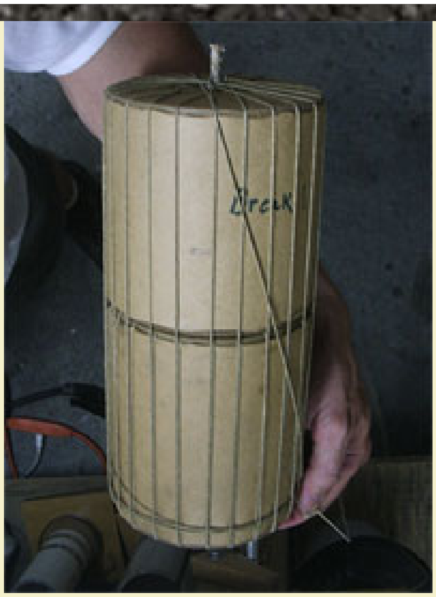

Figure 13: The first break is now vertically spiked onto the second break.

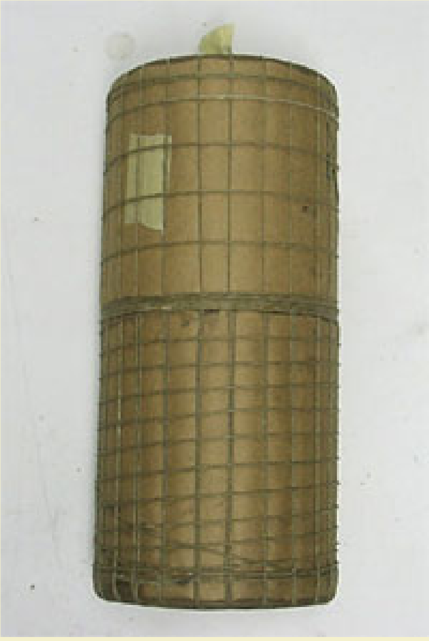

Figure 14: Horizontal spiking is applied to both breaks. Note the denser spiking for the color break compared with the insert break. Also note the tight grouping of twine at the junction between the two breaks.

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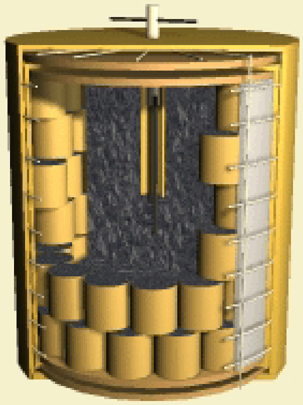
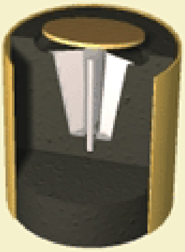
Build This...

6" Crossette Canister Shell





March, 2003 Issue

Letter from the Editor:
Political Fireworks
Important Notice!

Build This:
6" Crossette Canister Shell

Technique:
Creating Shows with ShowSim

Tool Tip:
Making Cross Match

Autopsy:
3" Vulcan Canister

Class C Corner:
Big Package, Reflection

Summary:
Crossettes are among the more tricky effects to master, and this article shows many of the tricks for getting them to work properly. A method is shown for making clean breaking charcoal crossettes without the distracting white flash typical of flash broke crossettes.

The shell itself is constructed using a Maltese-Italian hybrid, showing one of the several ways these two shell building techniques can be combined to lower costs and make construction easier.

Materials:

- (1) 10" x 36" long poster board
- (1) 10.5" x 36" long 60lb kraft
- (1) 36" long x cut to width 30lb kraft
- (3) 24" long x cut to width 70lb virgin kraft
- (4) 5.5" dia. 1/8" thick chipboard disks
- (1) 3.5" long spolette tube
- (40) 3/4" dia. chipboard disks
- (40) 2.5" x 8.5" long 30lb kraft

Tools:

- Spiking horse
- 1-1/4" crossette pump
- Arbor press or mallet
- Thin metal blade

Unmeasured Materials:

chinese fuse or termolite, 4Fg, 2FA, meal powder, flax twine, sawdust, black match, white glue, wheat paste

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6" Crossette Canister Shell

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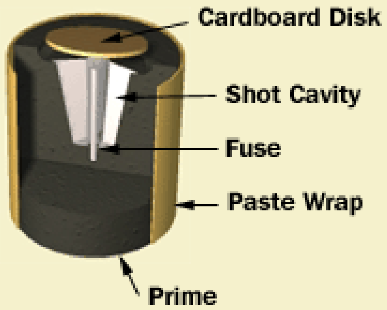


Figure 1: Basic crossette components.

Introduction:
Crossettes, also called split comets, are a special breed of comet that split into four pieces midway through their trajectory. Figure 1 shows a cross section of a typical crossette, which reveals an inner cavity where a high-energy break charge is placed. The comet is pasted in on the sides and top so that it can only burn from one end. When the flame front reaches the inner cavity, the burst charge blows the remainder of the comet into four pieces (ideally).

The inner cavity of a crossette is usually a tapered hole with the profile of a four pointed star or square. Although it is possible to make crossettes with a rounded cavity, the weak points caused by a four pointed polygon help insure that the comet breaks into four equal sized pieces. The taper is neccessary to ease the removal of comets from the pump after pressing, where they are fragile and prone to cracking.

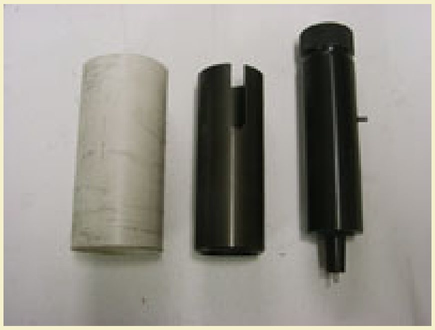
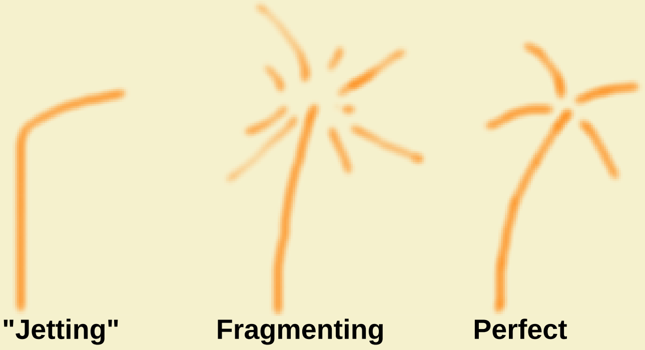


Figure 2: Crossette pump and PVC sleeve.

Crossette shells typically suffer from two problems: crossettes that don't break properly and crossettes that don't all break at the same time. The first step in making a crossette shell is to make sure your crossettes break properly through repeated testing from a star gun. The illustration below shows two of the most common crossette failures seen when testing individual crossettes.



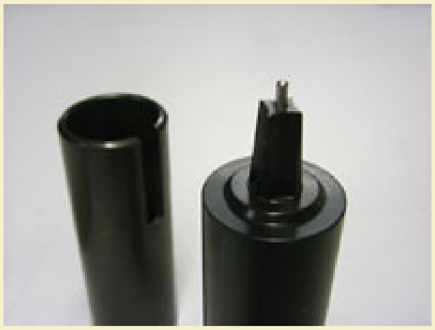


Figure 3: Star shaped cavity former with pin at tip.

Jetting is the most common problem and can be caused by a number of factors. It most often occurs when testing from a star gun, since the setback from the lift can compact the break charge into one side of the cavity and turn the crossette into an end burning rocket. This is why it is important to test your crossettes from a star gun rather than just placing them on a post or hanging them from a string. Star guns create the actual conditions your crossettes will experience when being thrown from a shell, whereas other methods do not and may lead you to think that your crossettes are working only to find that many of them fail when fired from a shell.

The use of too little or too weak of a break charge can also cause jetting. Since the cavity can not hold much powder, a high strength flash type mix must be used. The types of aluminum used for the flash will effect it's strength, with Indian Blackhead being the strongest, followed by German Black and then American Dark.

Another method some builders prefer is to hand roll small firecracker-like "shots" that fit into the cavity, thus insuring that the charge will have adequate confinement to split the comet apart. I personally find that this method adds too much work to a component that is already a lot of work as it is!

The most common trick to eliminate jetting is the use of a fuse that inserts into a small hole at the bottom of the cavity. Most commercial crossette pumps have a pin at the end of the plunger, as seen in Figure 3, which is designed specifically for this purpose. The flame front will reach the small hole first, allowing ignition of the cavity while there is still some composition left at the bottom to help create containment. The passfire fuse, which runs the full length of the cavity, also helps eliminate the end-burner problem by providing a fire gap through any comp that may otherwise get compacted from setback.

Thermolite is the most common choice of passfire for the small inner fuse, probably because it is one of the few types of fuse that is thin enough to actually fit into the hole. However, Thermolite is quite expensive and is increasingly hard to find. I have not had much luck with thin diameter visco fuse as an alternative, as the burn rate is too slow.

My personal secret is the use of hand rolled Chinese paper fuse made from corning dust. This type of fuse is ideal since it is thin, takes fire easily and is very fast burning. For those of you who don't make black powder, corning dust is the fine grained dust leftover when granulating BP. It ranges in particle size from meal to 60 mesh and burns quite rapidly when made into tissue fuse. Corning dust could also be made from pulverizing commercial BP by hand, or screening dampened meal through a 40-50 mesh screen. The procedure for making Chinese paper fuses can be found here.

The other common crossette defect is an overly hard break that causes many small pieces instead of four large pieces. This is a simple matter of dialing in the strength and amount of break used in the crossette. The paste wrap around the crossette should also not be too thick. Two turns of a light weight 30-40 lb kraft paper is all that is required.

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6" Crossette Canister Shell

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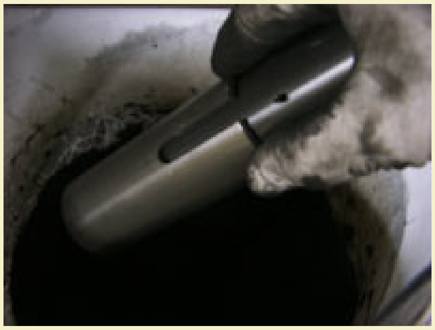

Figure 4: Pin position when loading comp.

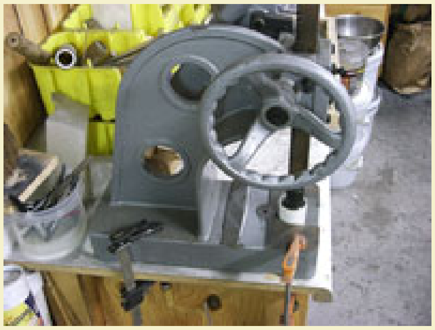

Figure 5: Arbor press used to compress comp.

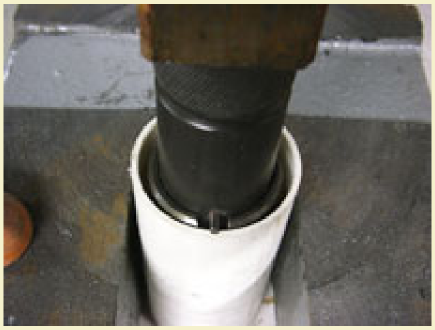

Figure 6: PVC sleeve used as depth stop.

Pumping Crossettes:
The crossettes used in this 6" shell are made using the 1-1/4" Nituff coated crossette pump made by Rich Wolter, which can be purchased from his website. Note that there are no paid product endorsements on Passfire.com. Anything that is recommended on this site is found to be of exceptional quality, and Rich's tools fit that qualification.

The crossettes for this project are traditional charcoal streamer crossettes. The formula used is Shimizu's Tiger Tail streamer. You will need to mix up 1000g of this composition to make the 40 comets required to build the shell. A 1000g batch will also give you a few extra comets to trial and error with before building the shell. I prefer to mix half of the required charcoal with all the other ingredients in a ball mill for one hour, then screening in the remainder of charcoal afterwards. This gives a nice bushy head on the comet while still leaving behind a tail of decent length. You can vary the mesh size of the screened in charcoal to adjust the tail duration as well.

Begin by dampening the 1000g batch of Tiger Tail with 15% of water that has 20% isopropyl alcohol added to it. Note that isopropyl is typically 30% water, so your effective alcohol content is really only 14%. This percentage is not real critical, as the alcohol is only there to break the surface tension of the water (for easier incorporation into the comp) and to speed up drying.

I find the fastest way to get the water completely incorporated into the powder is to work it in a little by hand and then pound it all down into a solid mass in the bottom of the bucket. This allows the water to absorb equally through the solid mass instead of spending all your effort kneading the powder by hand or pushing it through a screen to break up lumps. Allow the mass to sit a few minutes, then scrape it back up and pound it flat one more time. Chip it back up into a loose mix again and you are ready to go.

Comet pumps have a pin on the plunger that is designed as a depth stop. This allows you to pump comets that are of equal length, which is even more important with crossettes. If your crossettes are not all the same length, they will break at staggered times and ruin the effect, not to mention present problems when stacking rows inside the shell casing.

For regular comets, the plunger is pressed until the pin contacts the sleeve, then the plunger is rotated until the pin is above the slot so that the comet can be ejected. Crossettes present a problem, however, since twisting the plunger in this way will carve out the star shaped cavity and defeat its purpose. The pin must be positioned above the slot before pressing the comet in order to avoid this problem.

Since I think the depth stop concept is critical to getting uniform comet lengths, I place the comet pump inside a PVC sleeve that is cut to the same

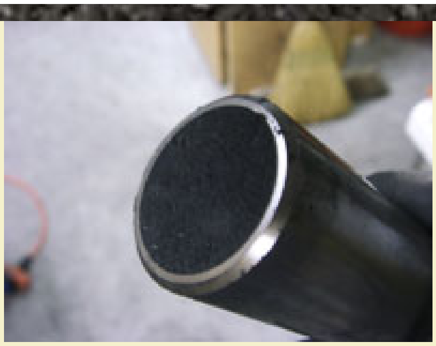

Figure 7: Composition shaved flush with end of pump after pressing.

length as the comet pump sleeve. This way the pin will hit the PVC sleeve, as seen in Figure 6, and create comets of equal length. If you had an exceptionally slow burning comet mix, you could make the sleeve even shorter in order to shorten the burn time of the comet. This same trick can be applied to regular comets as well.

The comet pump is loaded by holding the rammer such that the pin is at least a half inch above rim of the sleeve, as shown in Figure 4. Holding the pump in this way, simply ram it down into the loose comp several times until it fills up. It is important to make sure the pin stays a consistent height above the sleeve when doing this so that each comet will have roughly the same amount of composition pressed into it.

While a mallet can be used to consolidate these comets, I prefer the use of an arbor press because it is quieter, faster and less physical work. Figure 5 shows a typical arbor press in the 2 ton range. This ratchet type press with the quick-position wheel is highly recommended for it's speed and ease of operation. Because the comet pump is so long, it must be pressed against the table under the press. This requires that the press be firmly clamped to the table to keep from lifting itself during pressing, which is achieved with the bar clamps seen in Figure 5.

Once the comet is pressed and the pin hits the PVC sleeve, the pump is removed and the end is shaved flush with a thin blade as seen in Figure 7. Again, consistent comet length is critical and this last step insures that all comets will be the same length.

Lastly the plunger is pressed until the pin hits the bottom of the U shaped channel, then the comet is gently removed and placed on a screen to dry. Charcoal streamers are slow to dry, so allow at least a week before testing one. It is always good to make an extra one to break apart at various times to check for dryness.

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6" Crossette Canister Shell

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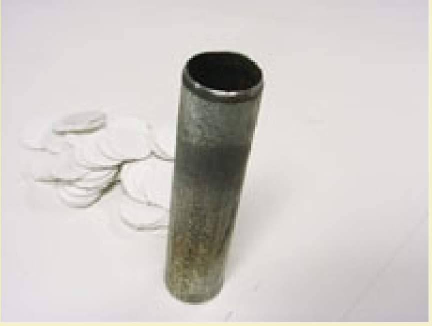

Figure 8: Tapered 1" conduit used as disk punch.

Punching End Disks:

While you can buy thin 3/4" diameter chipboard disks to use for the ends of your crossettes, you can also make your own pretty easily. A standard piece of 1" metal electrical conduit will make the perfect size disks for snugly fitting into the recess on top of a 1-1/4" crossette. Simply use a grinder to bevel the cutting edge of one end, as seen in Figure 8. After you have a nice 45 degree angle around the edge, use a propane torch to heat the conduit until it glows red hot, then immediately submerge it into a bucket of cold water. This will help harden the edge for a longer cutting life.

The disks used for the tops of crossettes do not need to be thick. Simple poster board makes good disks, and you can punch through two or three sheets at a time. I like to use a 4 lb sledge hammer to punch disks over a block of hard maple, as seen in Figure 9.

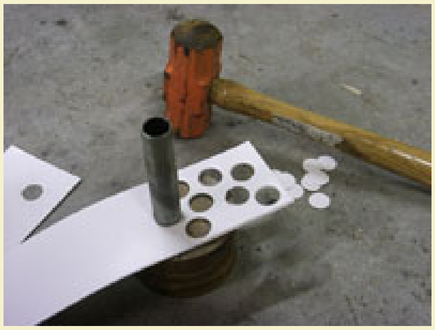

Figure 9: Punching poster board disks on a wooden block.

Crossette Burst Charges:

There are several burst charges commonly used in crossettes, most of them involving flash powder of some kind. While standard 70/30 flash can be used to break crossettes, the amount has to be carefully regulated to keep from blowing the crossette to bits. This type of charge also has the disadvantage of creating a bright flash when the crossettes break. If the crossette is made from a bright mix such as silver flitter, then this flash isn't noticeable as much. But for low light charcoal effects, this flash is very distracting and takes away from the quality of the streamer effect.

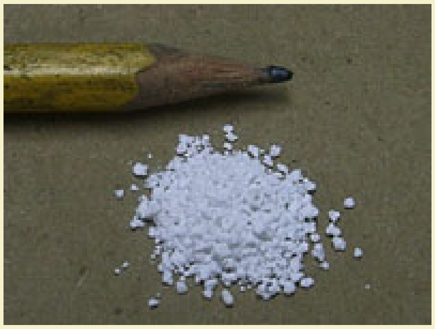

Figure 10: Granulated whistle mix.

Several variations of what is called "Dark Flash" exist, which involve the use of chlorate and antimony, with sulfur sometimes added. Chlorate/antimony/sulfur mixtures are very friction sensitive, so these mixtures require the utmost care when mixing. Only small batches of about 30 grams should be mixed at a time.

Dark Flash Compositions

	A	B	B
Potassium chlorate	1	4	3
Antimony Sulfide	1	1	2
Sulfur		1	1

Source: *Pyrotechnica XI*

Use of granulated whistle mix is another way to break a charcoal crossette without creating a bright flash. This will not break the crossette very hard, but it will split the crossette into four pieces when the mixture is granulated correctly. A mixture of 70/30 whistle mix is first dampened to a crumbly consistency with a mixture of water and gum arabic (1 quart of water per 30g gum arabic). This is then passed through a 50 mesh screen and allowed to dry. The resulting granulated whistle mix is shown in Figure 10.

Since the whistle mix is not quite as strong as regular 70/30 flash powder, the entire cavity must be filled with the mixture. The finer your granulations are, the stronger the break will be. However, you can not get away with just using ungranulated whistle mix, as it will compact easily and result in jetting. The fast burning center fuse shown in Figure 11 is also important to insure proper operation.

Finishing the Crossettes:
For testing purposes, foil tape or masking tape can be used to wrap the crossettes prior to firing from a star gun. This allows a faster trial and error period, since each crossette can be tweaked and fired one at a time without waiting for a pasted wrapper to dry. Simply apply two turns of 2" wide tape around the crossette and fold it over on the top. Make sure there are no gaps under the tape that would allow fire to travel up the side of the comet. Hot glue can be used to glue on the end disk for each trial. You can try different center fuses, different break charges and different amounts of break charge until you get a properly working crossette.

Once your crossettes are dialed in, it is time to mass produce the rest of them. To finish them off using my whistle mix method, first insert a piece of the Chinese fuse and cut it flush with the top of the cavity, as shown in Figure 11. The cavity is now filled with the granulated whistle mix, a bead of white glue is run around the rim and a paper disk placed on top.

Once the glue has completely dried, the comets are pasted in with two turns of 30-40 lb kraft paper. The paper can be virgin or recycled, it doesn't matter. The pasted paper should be as wide as the height of the comet plus it's diameter, and long enough to make two turns around the comet. Figure 14 shows crossettes being pasted in from a stack of pasted paper strips.

Note that some builders simply use the tape method for all their crossettes. I find the tape is actually more work when doing many crossettes, since it has to be smoothed down and is more prone to wrinkles along the sides that will cause timing defects. Some builders avoid wrapping the crossettes altogether and simply dip them in hot wax. This produces a perfect fireproof seal around the sides and top, and is a quick method as well.

Once your crossettes are fully dried, apply a slurry prime over the exposed end and dip the end into a container of 4Fg grain powder. This last step provides a primed surface that takes fire very easily and quickly.

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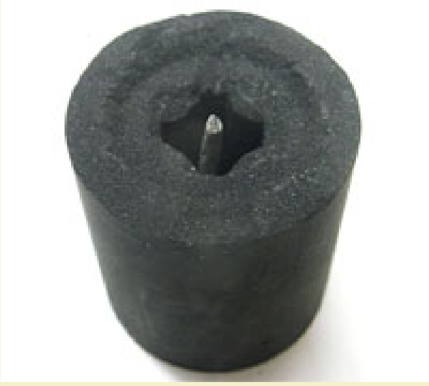

Figure 11: Chinese fuse inserted and cut flush with top of cavity.

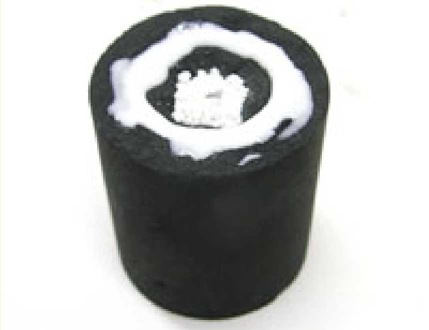

Figure 12: Cavity filled with whistle mix and glued around rim.

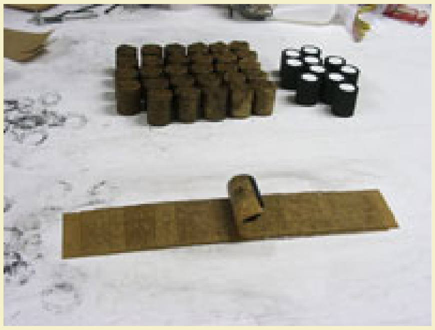

Figure 13: Pasting in crossettes from a stack of pasted strips.

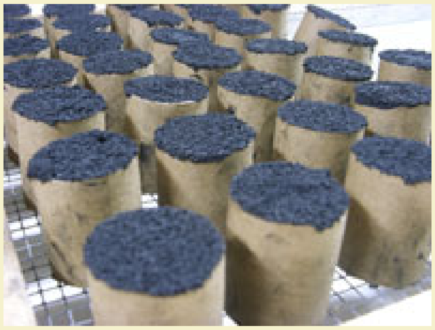

Figure 14: Primed ends dipped in 4Fg insures ignition.

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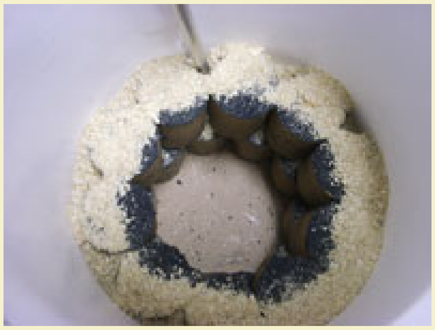
Figure 15: Tamping sawdust around gaps behind crossettes.

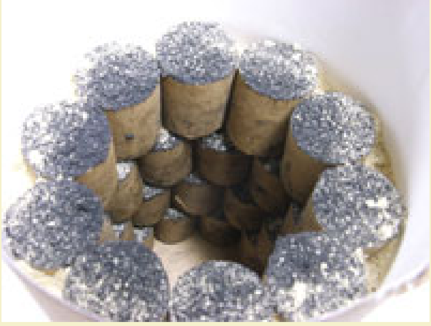
Figure 16: All crossettes loaded into a Maltese style can.

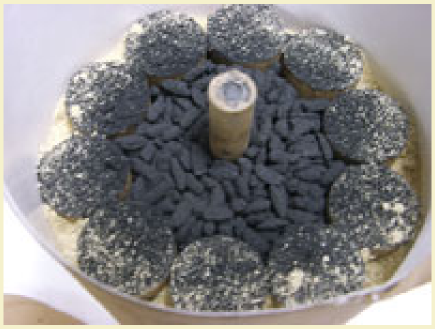
Figure 17: BP on puffed rice break charge filled in around a spolette.

Constructing the Shell:
This shell is constructed using a Maltese style can, which is constructed as shown here. The poster board strip is 10" x 36" long, while the 60lb recycled kraft strip is 10.5" x 36" long. These are rolled around a case former that is 5.5" in diameter. This is a single break shell, so the bottom disks will not contain the hole shown in the article linked to above.

Since the traditional Italian method would require six turns of kraft paper around the former, pleating down this amount of paper can be a chore. Not only is the Maltese style can stronger, it is made from cheaper materials (virgin kraft is not required) and is quicker to produce for larger shells.

When many cylindrical inserts are loaded into a canister shell of this type, be they comets, salutes, tourbillions, shells etc., the symmetry of the break is proportional to how solidly these items are loaded into the shell. The shell contents should not be loosely stacked against the walls. Large gaps between the crossettes should be taken up using wedges, and the space behind the crossettes should be rammed with sawdust. After each row is loaded, the sawdust is poured around the edge and tamped down with a dowel rod, as seen in Figure 15. This locks the crossettes into place so that they do not fall out when the shell is inverted to dump out the remaining loose sawdust.

The crossettes are stacked into the shell like a brick wall, using 10 crossettes per ring running four rings tall. Figure 16 shows all four rows of crossettes loaded.

The remaining space left for the break charge is rather large, and using straight commercial black powder would be expensive, heavy and overkill to break this shell. A more effective break charge is the use of home made rough powder, which is made as described here. I prefer the use of puffed rice coated with BP in a 4:1 ratio, which consumes less BP and is a little stronger of a break charge than rough powder. The puffed rice type charge also makes the shell lighter than if it were filled solid with rough powder, thus reducing your lift charge requirements.

A hand rolled spolette is made from a 3.5" wide x 14.5" long file folder paper rolled around a 1/4" former. The technique for doing this is described here. This should produce a rock solid tube with a 1/2" outside diameter. The tube is rammed with enough meal to give a 3.5 second delay, which is a 1-1/4" long charge in my case. You will have to time your own powder to find the exact charge required for your own spolette. Otherwise Chinese time fuse can be substituted for the spolette.

Figure 17 shows the shell prior to closing. A disk is placed over the spolette and the remainder of the can is sliced into tabs and pleated down with glue. Note the white glue around the base of the spolette prior to applying the second end disk over the pleated tabs.

Now we finish the shell using the Italian method of spiking and pasting. This is done to avoid the more tedious Maltese spiking process, which tends to consume a lot of twine and takes longer to apply. Figure 19 shows the spiked shell finished with 26 verticals of strong Italian flax twine.

One thing to be aware of when using Maltese cans is the gaps that lead into the can from the outside where the tabs were cut. Extra care must be taken to seal the outside of the spiked shell to ensure that lift gases do not get under the paste wrap and enter the shell through these slits at each end of the can. An initial paste wrap of 30lb kraft is used to form a good seal, since the thin paper lays down better and fully conforms around the spiking twine. Make sure this first paste wrap lays tightly around the base of the spolette.

The final paste wrap consists of three 24" long sheets of virgin 70lb kraft, grain short as usual.

Figure 21 shows the passfire connection to the spolette, which is made by baring a few inches of match and tying it over the exposed powder core using several turns of twine. I prefer waxed twine for its strong grip on the spolette, reducing the chances that the match could get torn away from the spolette before it takes fire.

The leader is connected to the passfire by looping exposed match around it and back up into the leader pipe for about four inches. This helps prevent the leader from getting yanked out of the shell when being lowered into the mortar. It also doubles the amount of match present at the connection point, producing a bigger flash of fire to help ignite the match passing over the spolette.

If you used charcoal crossettes and BP coated puffed rice as the break charge, you will only need about 100g of 2FA to lift this shell. Use an ounce of 2FA per pound of shell weight to determine the correct amount of lift for your own shell.

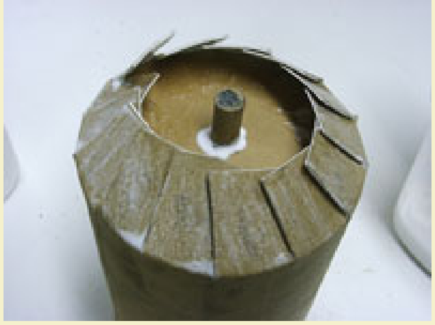
Figure 18: Closing the can in the Maltese style.

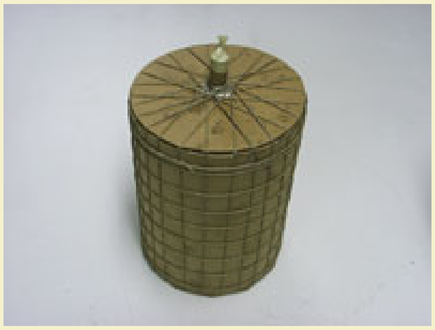
Figure 19: Can is spiked with flax twine as for an Italian shell.

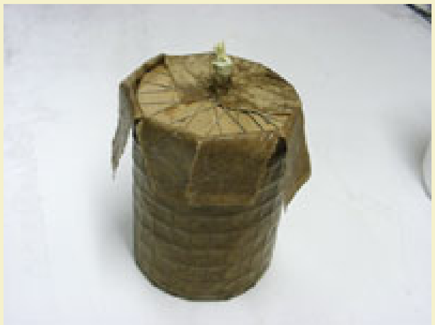
Figure 20: Pasting an initial 30lb wrap to insure a good gas seal.

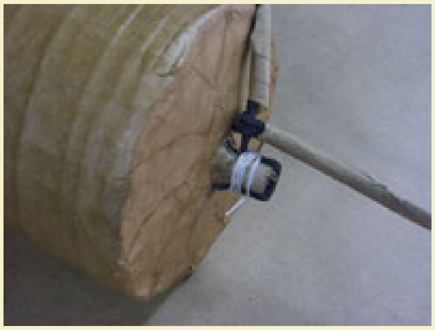
Figure 21: Leader to passfire fusing.

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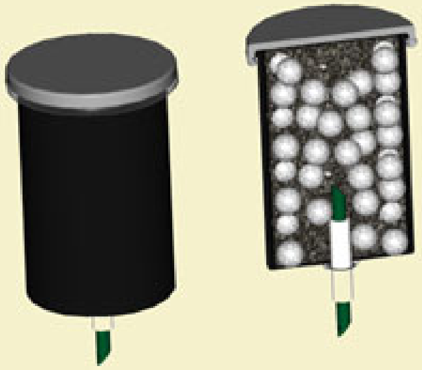
Beginner Project... **Page 1**

Film Canister Shells

by ***Michael Fales***



Introduction:

Film canisters are usually available in great quantity (and free), making them a prime candidate for small shell casings. Albeit small they can create a good burst if done properly. The film canisters used for this project are the standard black can with either the gray or black cap that fits over the top of the container. Other round type canisters will work as well, however they may need a different size mortar to launch them. The cap measures just less than 1-1/2" in diameter and the canister is 2" in height. Most camera shops have a stockpile of canisters that they are most willing to give away. I left one shop with two garbage bags full! Film canister shells are not only simple and cheap to construct, but can also be fired immediately after it is constructed, providing a quick fix for the pyro in need as well as providing a good method for testing stars.

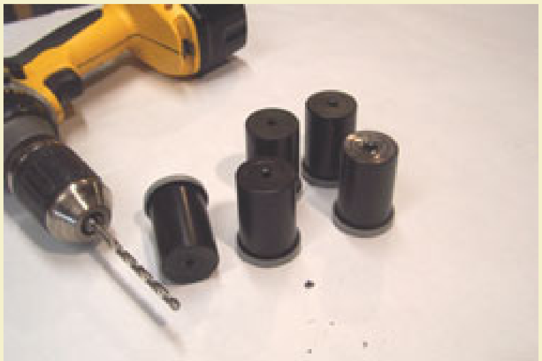


Figure 1: Drilling the fuse holes.

Making the shell:

To start, drill through the center of the film canister bottom with a 3/16" bit. This will provide a hole for which the time fuse can be pushed through. Commercial time fuse can be used, but is not really necessary. A homemade time fuse of sorts can be created by cutting a 1-1/2" length of green visco fuse. When cutting visco fuse, cut it at an angle so it will expose more of the powder core.

When making your own time fuse using visco, you will need to add an extra fire barrier around the fuse to keep the shell from igniting too early. This is because green visco burns through the side as it is burning, unlike real time fuse. Note that there is a grade of visco that does not burn through the side, known as "end spit" visco. The green visco is the "side spit" variety, while the red visco is the "end spit" type. If you have the red visco, you can skip the masking tape step described next and use a 1/8" hole in the bottom of your film canisters.

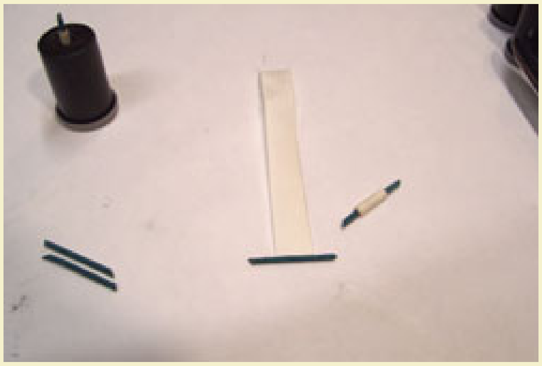


Figure 2: Insulating visco with masking tape.

Cut a 5.5" long piece of 3/4" wide masking tape and place the visco fuse at one end perpendicular to the tapes length. Make sure that nearly equal lengths of fuse extend to either side of the tape (see Figure 2). Roll the visco tightly into the tape creating a fire barrier. It is important to roll the fuse into the tape tight so that lift gases can not penetrate into the can on lift.

Insert the fuse into the hole on the film canister and push the tape portion half way in the canister. It should be tight enough that it takes some twisting, but does not damage the tape. The somewhat spongy nature of the masking tape combined with the flexible canister make a good compressed seal. Apply a bead of hot glue around the taped fuse on the outside of the canister to provide a good seal against the lift gases. Be sure that the cap is removed from the film canister when doing this step, otherwise air bubbles can be pushed out through the hot glue and possibly compromise your seal.

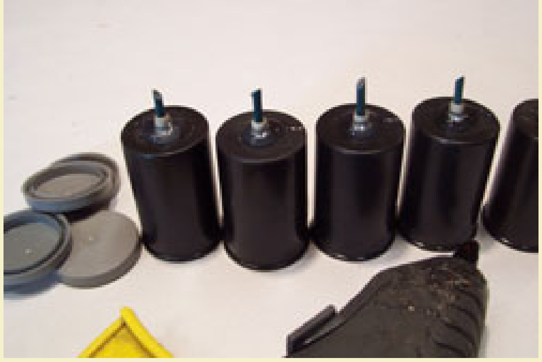


Figure 3: Hot gluing the time fuses in place.

Now to load the shell with the effects. Since the fuse of the shell is protruding from the bottom, it can not be set down level on the workspace. Drilling a 3/4" hole into a piece of wood will provide a place to set the canister so that both hands are free to work. Drilling several holes provides spaces to load many shells at one time, as seen in Figure 4.

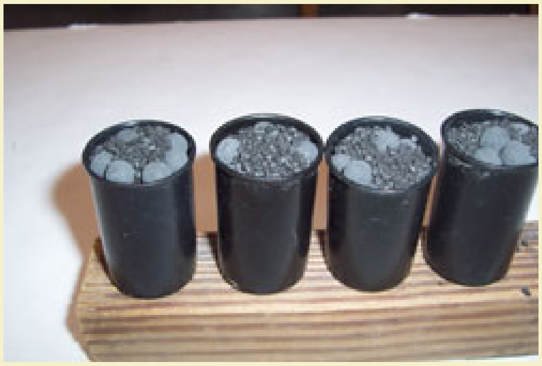


Figure 4: Shells loaded and ready to close.

Drop in 1/8" to 3/16" diameter stars until the canister is 1/3 full. Now sift in 3FA black powder in the space between the stars. Add 1/4 teaspoon 70/30 flash on top of the stars and tap the container to level the powder. Repeat by adding another 1/3 of the stars, black powder and 1/4 teaspoon of flash. Add the last 1/3 of the stars and black powder only, NO flash on this last addition. Level the stars and black powder to the top of the canister.

Once the canisters are loaded to the point seen in Figure 4, press on the cap while making sure that no powder is trapped between the cap and canister wall. Run a bead of hot glue under the rim of the cap to provide a seal between the canister and the cap. Avoid having the glue exceed the diameter of the cap, otherwise the shell could have problems fitting in the mortar.

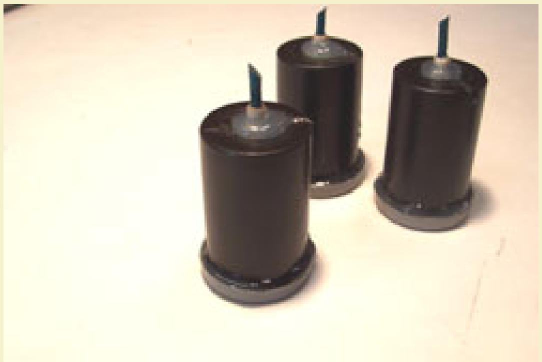


Figure 5: Securing the lids with hot glue.

Reinforcing:
This tiny canister will need better confinement yet to break nicely. Film canisters are made from a flexible type of plastic that does not provide much containment, which would result in weak and unsymmetrical breaks if used as-is. We will use standard 3/4" fiber reinforced strapping tape to wrap the shell with four vertical wraps. Cut a 14" length of the tape and split it down the middle lengthwise to create two 14" long x 3/8" wide strips. If you can find the 3/8" wide variety, it will save time. Start on top of the cap to one side and run the tape down the side at an angle so that it will pass the time fuse to one side. Run the tape up the back side of the shell crossing back to the side of the cap where you started and pass over the opposite side of the cap. Continue the tape down the side and pass the previous tape at an angle creating an "X" to pass the fuse on the other side. Bring the end of the tape up the back of the shell creating an "X" there as well. The strip of tape should end back on top of the cap. Now tape the shell with the other half strip of tape 90 degrees to the previous strip in the same manner passing the time fuse to either side. This is difficult to explain in words so please refer to Figures 6 and 7 to see what the pattern looks like.

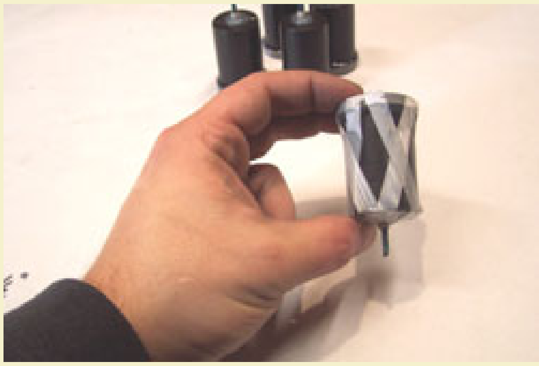


Figure 6: Wrapping with fiber tape.

Finish the shell by priming the exposed end of the visco fuse. Slit the end of the visco about 1/8" in and carefully spread open not letting the powder core fall out. Create a NC lacquer/Meal slurry and dip a small amount over the split fuse. Immediately dip the fuse into a fine grain black powder and leave to dry.

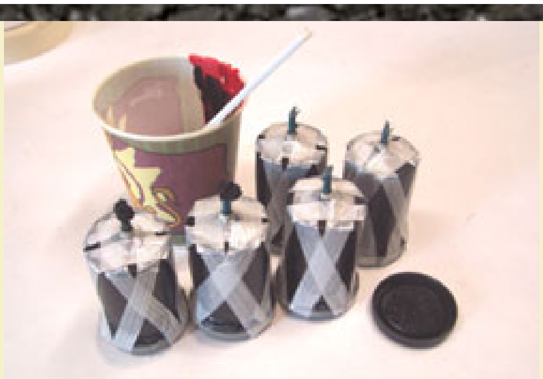


Figure 7: Priming the fuse ends.

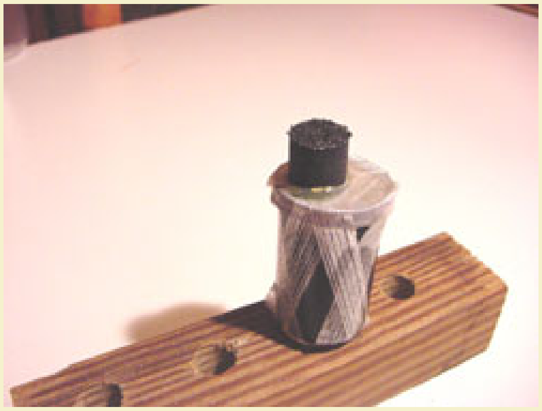


Figure 8: Attaching a rising comet.

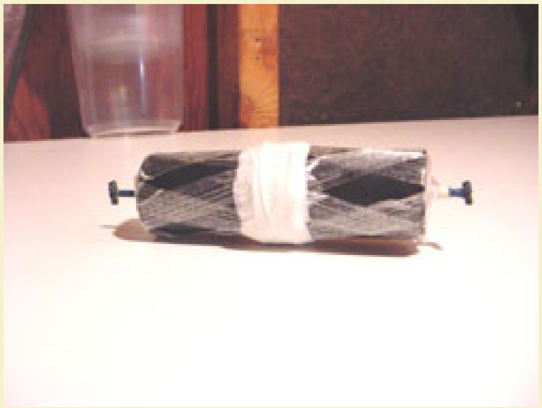


Figure 9: A two break arrangement.

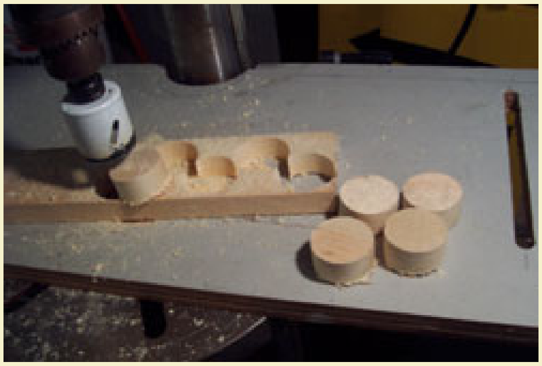


Figure 10: Using a hole cutter to make

Usage

These shells are launched from 1-1/2" to 1-5/8" diameter mortars. The mortars are bottom fused with visco by drilling a 1/8" hole just above the plug in the bottom of the mortar. A lift charge of 3/4 teaspoon of 4FG black powder is loaded into the mortar from above prior to loading the shell. The lift charge can vary somewhat depending on the weight of your shell, so some experimentation will be necessary to find the right amount. The shell is loaded after the lift charge by sliding it into the tube with the fuse side down until it reaches the bottom. If the mortar will be stored or transported, an end cap can be made by pressing a few disks of 40 lb kraft paper into the mortar using a rod that is slightly smaller than the mortar I.D.

1-1/2" spiral wound paper tubes make great mortars for these shells. Depending on the fit of your shell to the mortar more lift may be needed.

These shells are not particularly attractive to the eye and may draw unwanted attention of your nearest self proclaimed grand master, but they do make nice breaks for their size!

Extras:

Some simple additions can be made to enhance your film canister shells. You can create a rising tail by gluing a primed comet on top of the shell as seen in Figure 8. This is especially rewarding when firing the shells in fans or patterns. The pattern of the shells can be seen by the audience rather than just hearing the mortar fire and then seeing the shells burst a moment later. Put a dab of hot glue onto the top of your film canister shell and press a ½" tailing comet of your choice into the glue with the prime side up.

Double break canisters can also be made ever so simply! When creating the time fuse for your shells, use 1", rather than the ¾", wide masking tape for the second break shell. This will create the time delay needed to break the shells slightly apart. Finish the shells as before and place the two shells together cap to cap. Wrap a couple of turns of masking tape around the two caps to connect the two shells together. Be sure to prime the top shell heavily to make sure the lift gasses transfer fire to it. Launch as before but increase the lift to 1-1/4 teaspoon of 4FG black powder and slide the shell down with the primed time fuse end up. When launched, both time fuses will be lit and the first shell will break sending the other shell in another direction where it will break shortly after.

The minimal materials, cost, and time it takes to make these shells make them ideal for first time shell builders as well as experienced pyros looking to beef up their backyard displays on short notice.

mortar plugs.

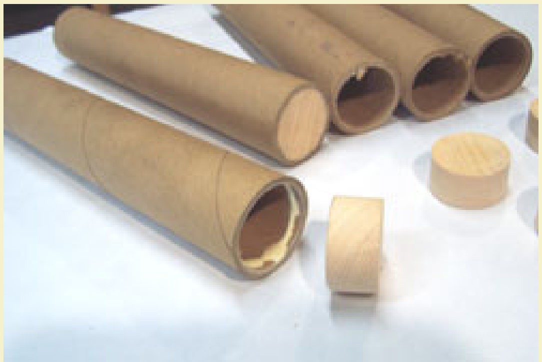


Figure 11: Securing wood plugs into cardboard mortars with wood glue.

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6" 3-Break Maltese Shell, Part I...

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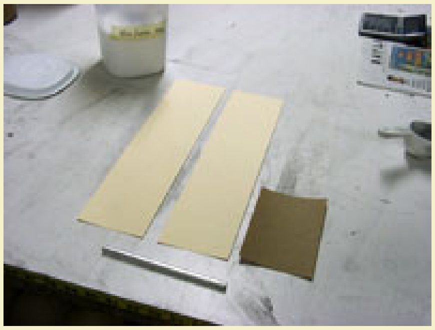

Figure 7: Two 14.5" strips of file folder paper and a piece of 30lb kraft for rolling spolettes.

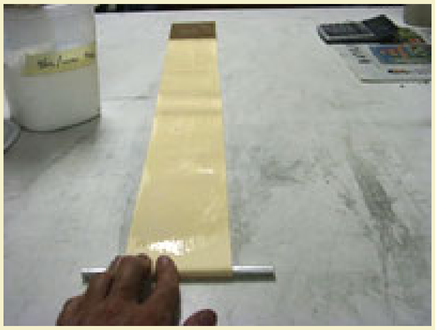

Figure 8: Strips are laid end to end and painted with a 50/50 mixture of white glue and water.

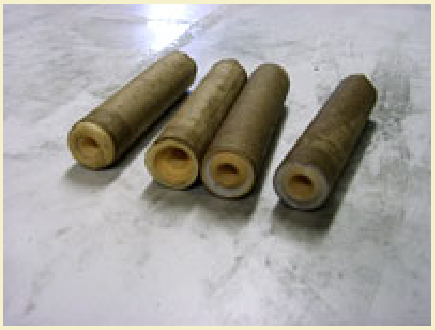

Figure 9: Finished spolette tubes ready for drying.

Making the Spolettes:
The type of tube used to make spolettes is very important. The inside diameter should be kept small, about 1/4", so that there is less surface area for the internal shell pressure to act on. The tube walls must be thick and made from strong paper in order to prevent the tube from splitting during loading. Because a lot of pressure will be acting on the powder charge when each break bursts, the powder must be rammed as hard as possible to lock it in place and prevent blow-through. Blow through occurs when the burst pressure of one break blows the spolette charge out the end of the tube and sets off the next break simultaneously, ruining the shell.

Tubes sold as "spolette tubes" by most hobby suppliers are inadequate for the job. While it is possible to find good quality spolette tubes, they can be expensive and often must be purchased in bulk quantities. For this project we will roll our own spolette tubes in a way similar to how the Maltese also make them.

An ideal paper for making spolettes is manila file folder paper. Using the legal size folders, which are 14.5" wide, cut two 3.5" wide strips for each spolette you will make (eight strips altogether). You will also need a 6" long strip of 30lb kraft that is also 3.5" wide. Figure 7 shows the paper and a 1/4" dia. aluminum rod used to roll the tube on.

Using a mixture of 50/50 white glue and water, paint the surface of the kraft strip first, then overlay a manila strip by 1/4" and fully coat it. Overlap the second manila strip by 1/4" and coat all of it except the last few inches. Begin rolling the tube from the dry end, as seen in Figure 8. If your paper is aligned straight and your rolling rod was perpendicular to the paper, you should get tubes that look like Figure 9. These should be 5/8" O.D. and fit snugly into the hole punched in your top disks. These tubes must be allowed to fully dry before loading.

The spolettes are rammed very hard with meal in several increments as if building a rocket, only there is no nozzle and the powder runs flush with one end of the tube. If your tubes came out concaved on one side, cut off a small length or sand them down to get the end level on the powder side. The other end does not need to be flush cut.

The burn time for these spolettes needs to be about 2 seconds each, and no more than that. Depending on how fast your powder is and how hard you ram it, this will be a charge of between 5/8" and 7/8". You will have to do timed trials with whatever meal you are using to determine the correct powder charge.

The Maltese do not drill back their powder cores, or even use the tapered rammer for the last increment (see spolette article). However, I find it easier to simply ram in three 1/4" teaspoon increments and then use a drill press with a depth-stop setting to drill through the excess comp to form a small hole that stops at the correct height of the powder core (see Figure 10). This not only achieves consistent and accurate timing across all spolettes, but also improves ignition on the passfire side. The more powder rammed into a spolette, the harder it is for burst pressure to blow through it. Thus, the drill-back method also decreases blow-through risk.

Once all the spolettes are loaded, two turns of 30 lb kraft are rolled around them so that about an inch of paper overhangs each end, as seen in Figure 11. A strip of paste is brushed down the center from end to end so that no gas can pass between the spolette tube and the paper.

Three sticks of black match are tied into the nosing paper on the passfire end, while the paper on the other end is twisted around the exposed powder core as a protective covering.

More...

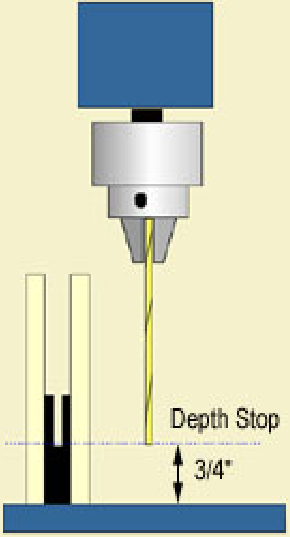

Figure 10: Using a drill press to drill back spolettes.

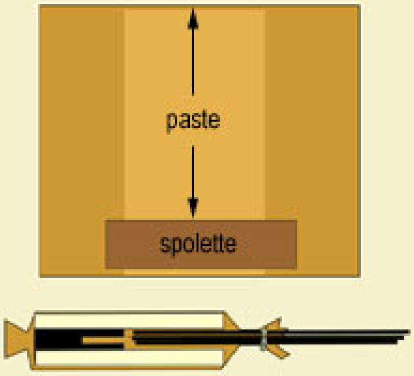

Figure 11: Rolling on the nosing paper and tied in black match.

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Troubleshooting...

Page 1

Shell Lift Failures

Introduction:
Of the two general classes of shell failure that can occur, during lift and during break, it is the lift failures that are the most disappointing. Nothing is worse than spending many hours building a complex shell only to have it flowerpot out of the mortar. This often leaves one thinking "I could have achieved the same effect in much less time by just throwing all the components into a sandwich-bag mine!" As such, there is usually the feeling of great relief when any large or labor intensive shell makes it out of the gun with its lit spolette spiraling through the air!

This article examines some of the most common causes of lift failure for both round shells and canister shells.

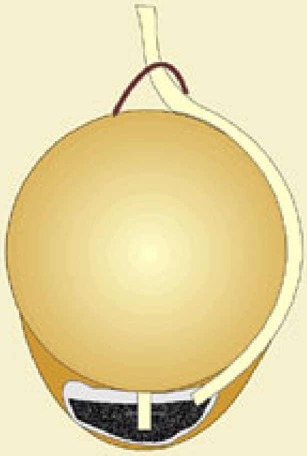

Figure 1: Placing the lift charge in a plastic bag to reduce the potential for water damage.

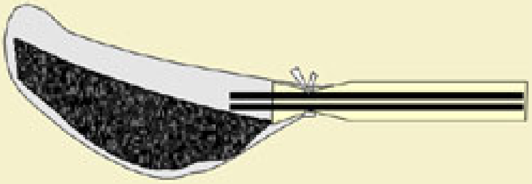

Figure 2: Multiple strands of black match allow central air gaps in the pipe, protecting against fire blocks caused by pipe constrictions.

Ingnition Failure:

This type of failure occurs when the shell fails to fire after it is lit.

Wet or Damp Lift Charge - mortars stored outside often have water in the bottom of them, which quickly absorb into your paper shell and ruin your lift charge. Rain that occurs after the shell has been loaded can be equally destructive. This type of failure can be protected against to some degree by loading your lift into a plastic sandwich bag prior to installing it into your shell. Some builders and commercial manufacturers will bag the entire shell in plastic to protect against standing water or rain that occurs after a shell has been loaded.

Wet Leader - paper quickmatch leaders can also absorb water and transfer it to the black powder strands inside. This is usually caused by rain, but in some cases the black residue inside recently fired mortars can work its way into the match pipe of snug fitting canister shells. While quickmatch is pretty resistant to failure caused by dead spots in the fuse, certain circumstances will still cause failure. Some brands of commercial quickmatch now have a plastic wrapper on the outside in order to prevent this type of failure.

Choked Leader - if the quickmatch pipe is constricted around the blackmatch strands so tightly that air can not easily flow pas the constriction, ignition failure can occur. This can happen when

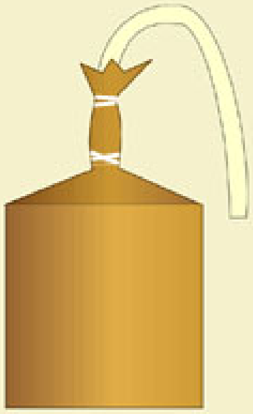

Figure 3: Securing leader with two separate ties instead of one.

tying the leader into the lift bag if the string is pulled too tight, especially if only one strand of blackmatch is used inside. The problem is considerably less likely if more than one match strand is used inside the pipe. Using multiple strands of blackmatch when making your own quickmatch is recommended to avoid ignition problems in general, even when no constrictions exist.

Pulled Leader - this cause is more common with canister shells and results from the temptation to use the match leader as a rope for lowering the shell into the mortar. Depending on how the fusing is done, several failure types can result from pulled or partially pulled leaders caused during loading. Preventive measures include 1) securing the leader with two separate ties around the shell wrapper, spaced a few inches apart 2) using waxed linen twine when tying blackmatch over spolettes 3) using virgin kraft if rolling your own match pipes and 4) avoid using shell leaders to lower shells weighing much over a few pounds.

Of all the things that can go wrong, ignition failures are about the only type that can be repaired, since the shell is left intact. Extreme caution must be used however, since a live shell that has had fire on the powder train now sits in the bottom of the mortar in an unknown state. Allow several hours before attempting to remove the shell, as small "cherries" of nitrate-soaked string can smolder for unpredictably long periods of time before unexpectedly bridging dead spots in the black match and firing the shell. The shell should be removed by pulling the mortar and dumping the shell from it without ever placing any body parts into the would-be trajectory should it fire.

More...

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Shell Lift Failures...

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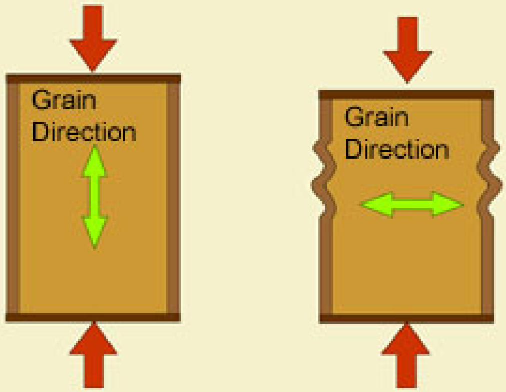

Figure 4: Compression resistance relative to paper grain direction.

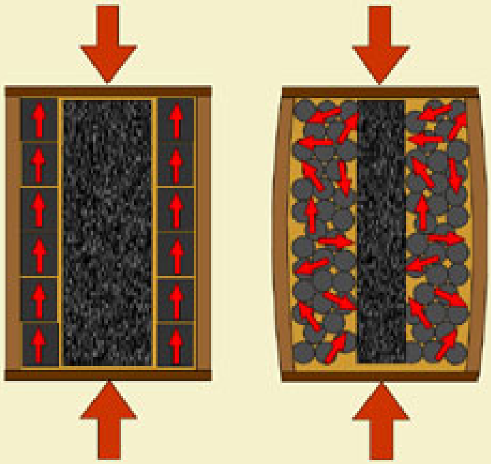

Figure 5: Internal force transfer vectors for stacked comets compared with round stars in a shell compressed during lift.

Flower Pot:

This is the term given to the type of failure where the shell explodes in the mortar.

Gas Leak - if there are any open pinholes around the time fuse or defects in the pasted outer casing, the high pressure gases generated before the shell leaves the mortar can get inside the shell and set it off. With paper ball shells this type of defect is very rare, but with plastic ball shells it is more common. Plastic shells can have small cracks in the seams where the hemispheres are glued together, or pin holes around the time fuse where it is glued in place. Care must be taken to glue plastic shells together with a solid bead of glue to avoid this.

Canister shells that are bottom fused, meaning the time fuse faces the lift charge when the shell is fired, are more susceptible to flower potting due to gas leaks around the spolette. Unlike ball shells, which have a rounded surface to direct the lift gases around the fuse, not to mention a considerable amount of pasted paper around the time fuse, the ends of a canister shell are flat and thus exposed to more pressure per square inch. For this reason all but small single break canister shells are generally top fused.

Split Shell Wall - this type of defect can occur with larger canister shells that are either not loaded with stars properly or were rolled with the paper grain in the wrong direction (or both). Because the lift force builds so quickly under the shell, which is at rest, the effect is like smacking the bottom of the shell with a sledge hammer. The more mass the shell has, the more it will be subjected to compression forces before it starts to move. If the shell does not have the structural integrity to handle such compression forces, the shell will actually compress. This compression will cause the side wall to split and expose the contents to the hot lift gases, thus bursting one or more breaks in the mortar.

The longer and heavier the shell is, the more it is susceptible to this kind of failure. For a multi-break shell, the lowest break on the chain experiences the most compression, since it has the weight of the other breaks above it. Longer individual breaks are also more prone to compression than shorter ones when all other variables are held constant.

There are three basic measures you can take to reduce shell wall failure on canister shells. For large multi-breaks, every precaution available needs to be taken:

1) Stronger Casing - this means using thicker paper, more turns of paper and rolling with the grain aligned parallel with the length of the shell. A paper tube with the grain direction running circumferential to the tube is more compressible than one where the grain runs end to end, as illustrated in Figure 4. Think of the paper grain as tiny support columns. You want the columns running from top to bottom, not stacked on their sides. The goal is to make a casing that is as resistant to compression as possible.

2) Solid Internal Loading - even a strong case will still compress if the internal contents do not form a solid column of support inside the casing. Loosely loaded round stars are the poorest choice for internal support, while cut stars are more supportive and stacked pumped stars are the most supportive.

To visualize how different star geometries provide various degrees of structural integrity, imagine a paper lunch bag packed solid with similar shaped objects. If you stomp on a bag filled with round marbles, the bag will easily split and spew the marbles out the sides. If the bag is filled with square dice, it will not split as easily but still may rip slightly or require a harder stomp. If equal sized Lego blocks were stacked on top of each other to form a square brick wall, the bag would not split at all and you could put your full weight on it.

It is for this reason that large multi-break shells require pumped stars or cylindrical inserts to be stacked on top of each other in rings. An 8" multi-break filled with loose cut stars would not be able to withstand the crushing force, just like the bag of dice splits open in our analogy. Also note that any inserts used inside the shell must each be solid themselves, since the compression force will be transferred to everything inside the shell. In the case of large shells that must contain weak inserts, such as plastic lampare containers, additional support must be added inside the shell such as wooden dowel rods or very strong paper tubes that will keep the compression forces from crushing the fragile inserts.

In addition to the correct choice of internal components, any air gaps between and above the shell contents must be filled with a solid material such as pulverone or sand, otherwise the resulting air gap would allow the shell to compress and rupture.

3) Shock Absorption - since the compression force results from the rapid buildup of pressure over a very short period of time, another approach is to soften the impact with a less aggressive lifting mechanism. This involves using some kind of intentionally compressible material (crumpled wads of paper or cloth) between the shell and a piston plate placed above the lift chamber. As the piston plate rises, the material between it and the shell will compress, resulting in a slower transfer of lift force onto the shell. The Maltese employ this method to great effect, along with additional compressible material placed between each break of their large multi-break shells.

Crushed End Disk - this is similar to split shell wall, except the bottom of the shell casing caves inward instead of the side splitting outward. This is more common on larger diameter canister shells where the end disk has to span a larger area. Because the end of the shell is not curved, it is inherently weak and vulnerable to outside pressure caving it in, especially since the bottom disk takes the full brunt of the lift force.

This problem can be remedied by using multiple end disks stacked on top of each other to make a stronger disk. Applying glue between the disks will add considerably more resistance to bending compared with loosely stacked disks. Stronger material may also be used for the disk, such as kraft disks instead of chipboard disks. All the methods of internal loading mentioned above are also important for preventing the end disk from flexing inward. The Maltese shock absorption piston method of lifting shells also removes the crushed end disk problem completely.

Break-ups - long multi-break shells can actually split apart at the junction between two breaks as the shell leaves the mortar. It is quite common for the spolettes on each broken piece to take fire and operate normally on the way up, with the gaping hole left on the bottom of the top piece somehow mysteriously avoiding ignition. This phenomenon has been witnessed many times both in the US and in Malta, so there is more to it than a freak incident but nobody can really explain how it occurs. My guess is that the Bernoulli effect pulls a vacuum inside the shell as the air rushes past the open hole, thus preventing any hot gases from getting inside. This same effect has often been blamed for "sucking" the fire out of burning spolettes right at the moment of flame transfer to the burst charge, thus leading to the development of the conical spolette rammer.

The suggested cure to this type of malfunction would be more vertical strands of twine holding the breaks together, using stronger twine and/or pasting the shell in with more turns or stronger paper.

Passfire Failure - this is actually a type of ignition failure on a canister shell whereby the passfire down the side of the shell fails after the top spolette has already taken fire. The result is that the first break flower pots in the mortar, usually setting off the lift charge at the exact same time and sending the remaining breaks skyward. On very long shells the passfire often doesn't actually fail, rather becomes delayed due to constrictions while trying to get to the lift charge. The length of the hang-fire delay determines weather the failure is a flowerpot or a first break going off dangerously low.

This type of problem can be dealt with by using only the highest quality black match as your passfire link, or even making two separate side-by-side passfire links if you have the mortar clearance to permit this. Avoid constricting the passfire pipe in any way, and don't use twine to tie off the end or pinch it closed in any way. The more breaks your shell has, the shorter the first spolette delay will be and thus the more critical it is that the shell fires at the same time this fuse ignites. Even small passfire delays on a large multi-break can cause nasty low breaks.

Conclusion:

These are the most common causes and cures for shell problems that occur during lift. Since flowerpot failures typically destroy all the evidence, it can be difficult to ever know exactly what caused the problem. Gas leaks, shell ruptures and disk failures all have the same end result, so you are left to analyze the shell construction from memory and draw your own conclusions. But keeping these basic principles in mind, along with experience and attention to detail, will greatly reduce your CATO statistics!

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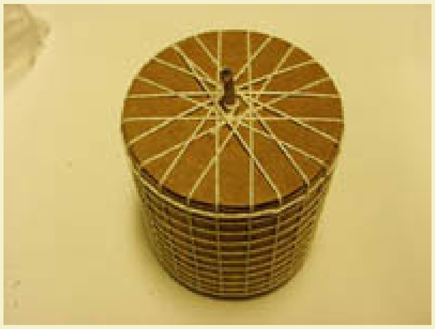
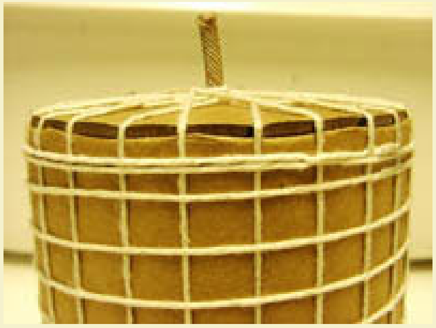
Off-Center Spiking Made Easy



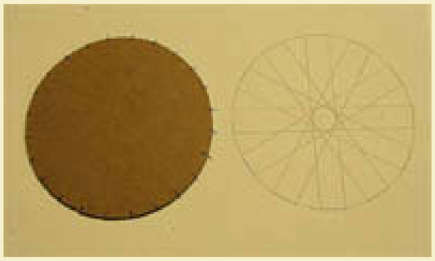
Off-center spiking on a 5" shell.

Off-center spiking is a less common method of stringing canister shells that offers several advantages over the more popular radial method. The off center method avoids the pileup of string around the time fuse that the radial method produces, which causes unwanted air gaps under the paste wrap of both the top and bottom of the finished shell. The stacking layers of string become even more pronounced on larger shells, and result in a conical lump toward the center of the finished shell. This central buildup becomes even more of a problem when stacking multi-break shells on top of one another, since the lump prevents one shell from sitting flat against the other. This can cause the shell to rock to the extent that it must be shimmed to keep it in line with the other breaks when spiking.



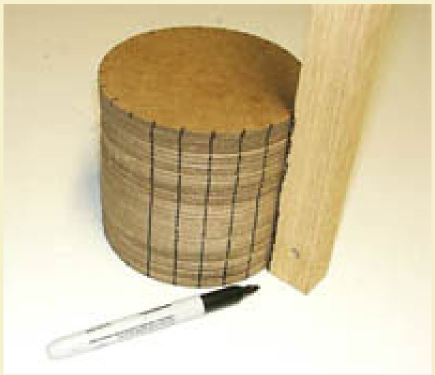
Note how flat the string lays on top.

The off-center method produces a very flat top and bottom that is ideal for stacking shells and attaching comets. However, this type of spiking is not one that can be visually spaced out, since there are no quadrants or perpendicular intersections of string for visual reference. Unless you can gauge 10 degree angles with your bare eyes, you are going to have to mark your end disks where the vertices will be. This sounds worse than it really is, since you can mark 20 or more disks in parallel using the method shown below.



Making the template disk.

First create a template disk by measuring out the edge points that correspond to the number of verticals for the size shell you are building. I use CorelDraw on a computer to accurately make the marking template image, then print it out. Some people even cut out the image from a printout and glue it right onto the end disk. The method shown here is quite faster though, and you don't need to see where the strings will cross the top of the shell, only the edge points. You only need to create this disk one time, then use it as a template for marking all other disks.



Marking many disks at once.

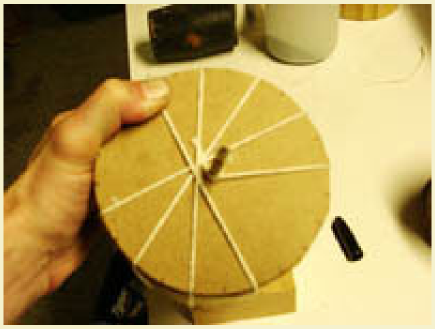
Now take your template disk and use it to mark the edges of two more disks. The marks only need to be on the edge of the disks and not on the face of them. These two disks are then placed on a large stack of disks, one on top and one on bottom. They are arranged so that the marks will line up with each other when a ruler is placed at right angle to the table. A straight edge and felt tip marker are now used to connect the marks from the top disk to the bottom disk, thus marking all the disks in between. Care must be taken not to rotate the disks when working, as it is difficult to realign them. A bar clamp can be used to clamp all disks firmly together at the edge of a table to prevent this shifting problem.

Make sure top and bottom disks line up.

With your marked disks glued in place, make sure that the disks are aligned so that the marks are directly across from each other. The time spent marking your disks will now pay off in rapid and precise no-brainer spiking. Your first loop is important to get right though. Pick a mark and string down to the bottom of the shell. Now find the mark that is directly across from where your string is, then string to the first mark to the right of that point. When you string back up to the top of the shell, you will do the same thing except you string to the first mark to the left of the center.

Right of center on bottom.

Left of center on top.



Pattern always skips a mark.

Now you continue the same rule over and over- right of center on the bottom and left of center on the top. This will form a pattern in which every other mark is skipped. Eventually the pattern wraps around and you fill in the empty spots and finish up exactly where you started. Finish the horizontal spiking the standard way as described in the spiking basics tutorial.

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Technique...

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Shell Spiking Basics

The process of strengthening a canister shell by wrapping it tightly in strong twine, known as "spiking", is the key to achieving a good break. While ball shells are naturally strong walled in all directions due to the symmetry of their spherical geometry, canister shells must be reinforced with twine to ensure comparable containment, symmetry and spread. A pattern of both vertically and horizontally placed twine is used for this purpose.

Vertical Spiking

Canister shells have a natural weak spot where the flat ends connect with the cylindrical walls. Without reinforcement, these ends would easily blow out one or both sides. Vertical spiking refers to the lengths of twine that run from top to bottom around the shell, preventing the end disks from blowing out. Weak string or an inadequate number of vertical strands will usually result in an undesirable dump break or bowtie break. In cases where these types of breaks are the desired effect, the vertical spiking can be reduced to help achieve them. The following table shows the typical number of vertical strands used for cotton twine. Verticals refers to the number of symmetrically spaced groupings of strands. When flax twine is used instead of cotton, the number of strands shown here can be halved while keeping the number of verticals the same.

Standard Spiking Patterns

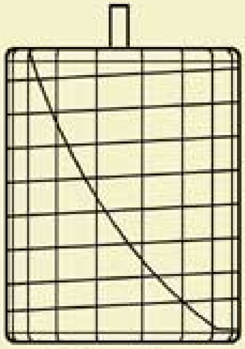
Shell Size	Verticals/Strands	Material
3"	12 / 2	8-ply cotton
4"	16 / 2	8 or 10-ply cotton
5"	24 / 2	8 or 10-ply cotton
6"	32 / 2	8 or 10-ply cotton
8"	48 / 2 or 48 / 3	8 or 10-ply cotton

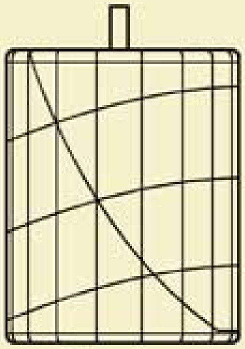
Source: *Pyrotechnica IX*

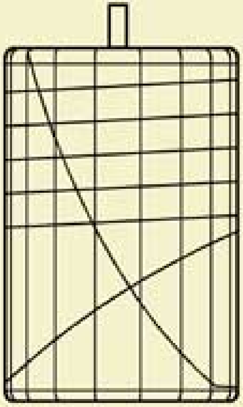
Horizontal Spiking

While vertical spiking secures the ends of the canister, horizontal spiking is used to strengthen the cylindrical walls of the shell. Without horizontal spiking, the chipboard and casing would rupture too easily and the contents would pop out a hole in the side, a defect known as a "hose break." The ideal break should shread the walls of the casing, leaving only the end disks intact. To help achieve this, twine is wrapped around the diameter of the shell a number of times in a spiral fashion, such that a grid is created with the intersections of the vertical spiking.

The distance between the turns of horizontal twine vary depending on what the contents of the shell are. For color breaks of just plain stars, the spacing should be roughly equal to the size of the star used in the shell. If the shell contains inserts of whistles, serpents or other shells that are to be blown out into a ring, then the spacing is widened considerably more. In the case that the shell was rolled around a bottom shot which has already been spiked and pasted, then virtually no horizontal spiking would be used for the part of the shell occupied by the salute, then finished with normal horizontal spiking for the remainder of the shell. The following diagrams illustrate different horizontal spiking patterns for different types of shells.


Color Stars


Inserts


Color Stars
with Inserts

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Shell Spiking Basics...

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Spiking Twine

The ideal spiking twine is very strong, absorbs paste, is not too thick and does not stretch under tension. Flax twine is highly recommended over cotton twine due to the fact that it doesn't stretch the way cotton does when tension is applied. However, the difficulty in finding good flax twine, not to mention its steep price tag, often leaves the builder with no choice but to use the cotton twine. Local industries that use flax twine can be a good place to start when locating a supplier. These include shoe makers, book binders and upholstery industries. The break strength and resistance to stretching should be tested prior to investing any money in a large quantity of twine. Take a two foot length and wrap each end around a piece of dowel rod to form T handles, then use these to try and pull the twine apart. Good twine should be very difficult to break in this manner. A long piece that is tied off to a solid object and spooled out should exhibit very little stretching when pulled tight.

Hemp twine is another suitable spiking twine that is quite strong and does not stretch. Jute twine is very weak even in thicker diameters, thus very poor for spiking. Most types of synthetic twine should be avoided due to their elastic quality and inability to hold knots. While polypropylene twine is very strong and does not stretch, it is not very cooperative in laying flat, does not hold knots well, has a slick surface that does not bite into the case and does not absorb paste at all.

The stretching that occurs with cotton twine can be greatly reduced by soaking it with paste prior to spiking. Paste can even be worked into the twine after it has already been spiked onto the shell prior to pasting it in. Another method some builders use is to pull the twine through a bucket of paste as it is being spiked onto the shell. An eyelet in the bottom of the bucket serves to pull the twine down into the paste as it moves from the spiking horse into the bucket, then back out to the shell.

Spiking Procedure

Since pictures are worth a thousand words, here is a step-by-step pictorial of spiking a single break color shell:

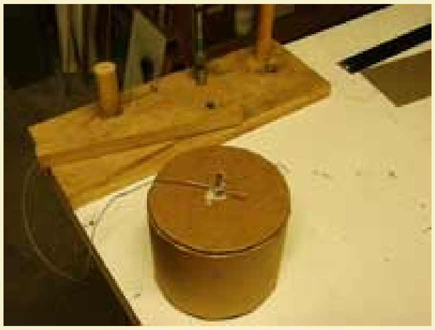

Figure 1: A bead of white glue is run around the time fuse, then the twine is tied off with a clove hitch.

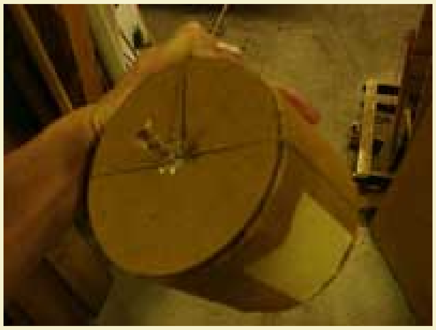

Figure 2: Start with the verticals first, keeping tension very tight.

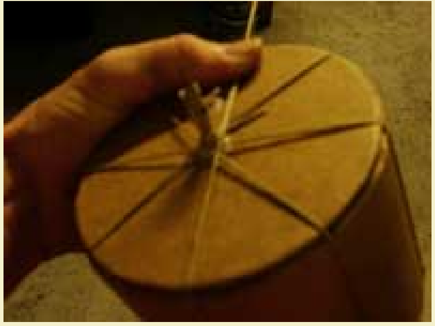
Figure 3: Each new set of verticals should divide the space left by the previous vertical in order to make judging the spacing easier.

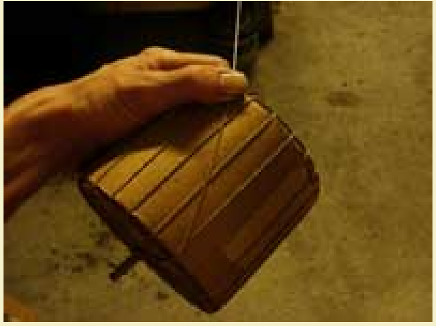
Figure 4: When the proper number of verticals have been completed, a diagonal is run down to the bottom of the shell.

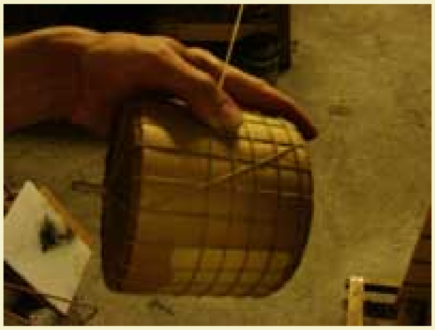
Figure 5: The horizontal spiral begins at the bottom and works it's way to the fuse end of the shell.

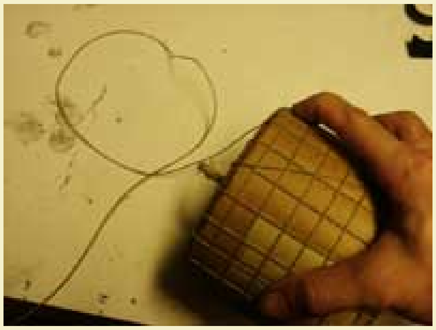
Figure 6: When the top is reached, a loop is made in the twine and slipped over the top of the shell.

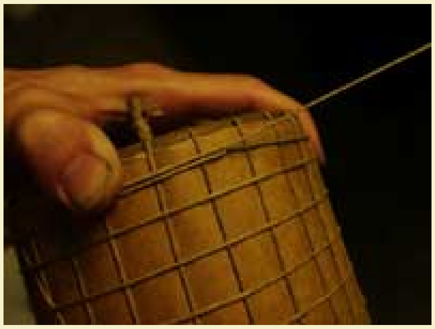
Figure 7: The loop should create the cinch mechanism as shown here.

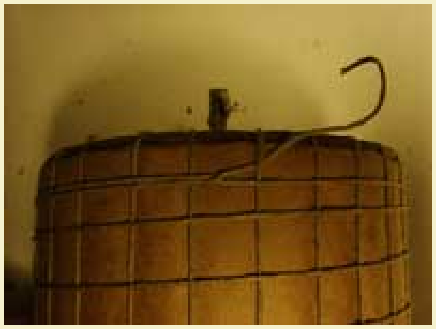
Figure 8: After cinching, the string is cut and passed under the closest vertical to hold it in place. The excess is cut short and the free end is held down with a dab of white glue.

The type of vertical spiking shown above is known as radial spiking, and has the disadvantage of creating a pileup of string around the time fuse. For a cleaner method of spiking, see the related article about off-center spiking.

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Design Notes...

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Time Fuse and Spolettes

Introduction:
There is probably no component more critical to the proper operation of any pyrotechnic device than it's fuse. This is especially true with aerial shells, where the fuse serves not only as an ignition device but also as a delay element.

The two types of fuse most commonly used for timing and ignition in aerial shells are time fuse and spolettes. These devices have three primary functions: 1) take fire 2) provide delay and 3) pass fire. This article will take a look at the design and construction of both commercial time fuse and home-made spolettes, as well as the advantages and disadvantages with each of them.

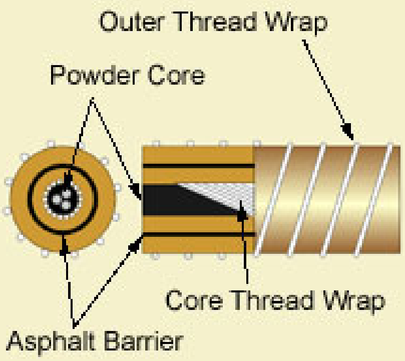

Figure 1: Cross section of typical Chinese time fuse.

Time Fuse:
Commercial time fuse is a type of mass produced fuse that is purchased in continuous rolls that are then cut to the desired size when needed. Several varieties exist, such as Japanese time fuse, Chinese time fuse, Bickford etc. While Japanese time fuse is the best quality available, the lower cost and availability of Chinese time fuse makes it the most popular choice for the hobbyist.

Time fuse is fabricated using a machine that produces continuous lengths of a cord-like fuse constructed as shown in Figure 1. A central powder core containing cotton twine coated with black powder is shrouded with a tight wrapper of small threads. This helps seal any gaps between the powder core and the paper cover that is formed around it, thus preventing unwanted fire propagation that would render the timing unreliable. Two kraft paper sleeves are tightly wound around the powder core, with a thin layer of asphalt between them. The asphalt creates a moisture barrier so that moisture absorbed during gluing and pasting does not absorb all the way to the powder core and damage the fuse. A final wrapping of twine helps keep the paper sleeve from unraveling during storage and use.

The burn rate for typical time fuse runs between 2 and 3 seconds per inch. Since the burn rate can vary even between different batches from the same manufacturer, it is always best to time a sample from a given spool prior to use. This is done by burning a longer piece, such as 10 inches or more, then dividing the burn time by the number of inches to get your rate.

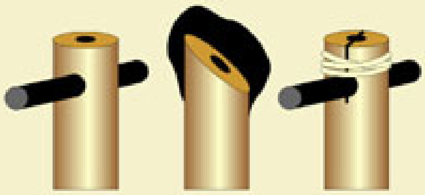

Figure 2: Methods of priming time fuse for taking fire.

Priming:

Figure 2 shows the three most common methods for priming time fuse so that it easily takes fire. Both ends of the time fuse are prepared in the same way, with the distances between the ignition points carefully measured to achieve the desired delay.

The first method involves punching a hole through the fuse at least 1/4" from the end of the fuse, then threading it with a small stick of black match. The time fuse is then squeezed at the junction to make sure the stick of match can not slide out from the centrifugal forces generated when the shell spins through the air. This method, known as "cross-matching," is fast and reliable, making it the most commonly used.

The second method, commonly used by the Chinese, relies on a slurry prime of black powder applied to both ends of the fuse. The ends of the time fuse are often cut at an angle in order to increase the exposed surface area of the powder core. While this method is faster than cross matching, it is less reliable. It is common for two redundant fuses to be used for each shell to insure ignition when using this prime method.

Another cross-matching method involves slicing the time fuse down the center from each end, inserting the cross match stick, and then tying the end closed with a piece of twine. While this is the most laborious method, it does not require any special punch tools and also insures that the cross match is held firmly in place.

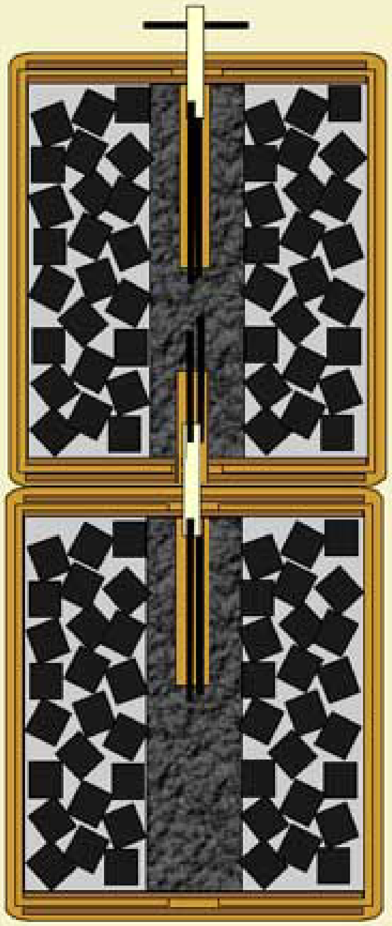

Figure 3: Time fuse used for two or three break shells.

Applications:

The popularity of Chinese time fuse is due to the fact that it is cheap and easy to use. While spolettes have to be manufactured one at a time by the hobbyist, time fuse is merely cut to the proper length and installed. The smaller diameter of time fuse also makes it less likely to blow into the casing from lift pressure or burst pressure in multi-break shells. There is also no risk of the powder core blowing through from lift and burst pressures, as is the case when using spolettes.

The main limitation with time fuse occurs when very short delays are needed, as when building multi-break shells. As seen in Figure 3, time fuse can be used for two and even three break shells where the delay between breaks is long enough to allow at least a 1" segment of fuse between cross match points. But as the number of breaks increase and the delay requirement decreases, the length of the fuse shrinks to the point that it can not protrude through the layer of paper, twine and disks that pile up where two breaks connect.

Other limitations with time fuse, when compared to spolettes, include a less vigorous transfer of fire to the inside of the shell, less precise timing and an inability to show the shells trajectory once fired from the mortar. However, as evidenced by the fact that commercial shells almost exclusively rely on time fuse, this type of fuse still performs quite well.

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Time Fuse and Spolettes...

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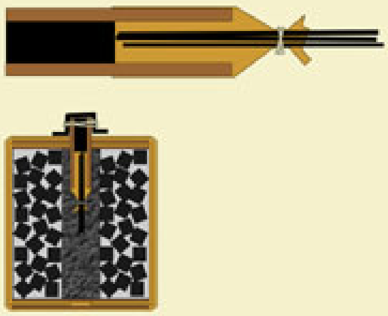

Figure 4: Typical spolette and placement in a canister shell.

Spolettes:
Spolettes are the traditional fuses used to transfer fire from the lift charge to the inside of aerial shells. The concept is quite simple: a small tube is charged with powder of a known burn rate such that it ignites at one end when the shell is fired, then burns through the other end when the shell reaches the proper height.

Figure 4 shows the construction of a typical spolette. The charge typically fills less than half the tube, depending on the delay requirement. Several sticks of black match are inserted into the tube and held in place with nosing paper and twine. The matched end is inserted into the shell, while the flush end protrudes about a half inch or more from the top of the shell. The flush end of the spolette is prepared by first scratching a line or two into the powder charge, which helps give the smooth, hard surface of the rammed powder some edges to aid in fire transfer. A stick or two of black match is then tied directly across the top of the spolette so that it comes into contact with the powder core.

Spolettes are usually made from thick walled tubes of strong virgin kraft paper, which are rammed with the appropriate increment of commercial meal powder to give the desired delay. The powder must be rammed tightly into the tube, since there are no clay plugs to hold the charge in place in the presence of high pressures such as those caused by lift or burst activity. Because spolettes must be rammed very hard, thin walled tubes or tubes made from inferior paper will split open during ramming.

Since tube strength is required only for loading purposes, as spolettes do not generate internal pressure the way a rocket does, lesser quality tubes may be used if they can be loaded without splitting. One trick to using cheaper tubes is to use a ramming block as shown in Figure 5. The block must be thick enough to support the tube for the entire length of the powder charge, and may also need to have a clamping mechanism that can be loosened once the loaded tube is to be removed.

The fastest burning meal possible is used due to the fact that the delay time is often only three to five seconds, which would result in a very thin charge if slow burning powder were used. Small powder charges present a problem known as "blow through," where the forces from lift or the burst pressure in a multi-break shell can blow the charge out the bottom of the spolette and ignite the shell contents prematurely. The smaller the charge is, the less friction there is between the powder core and the tube walls to hold the core in place while under pressure. Blow-through forces are also reduced by using a smaller I.D. for the spolette tube, which provides less powder surface area for the pressure to act on. Spolette tubes with 1/4" I.D.s are often used for this reason.

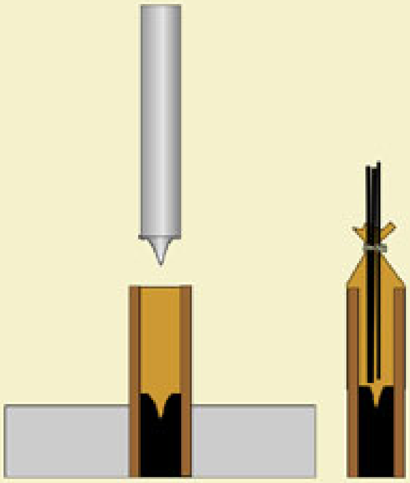

Figure 5: Rammer and base for making cavity on passfire end of spolette.

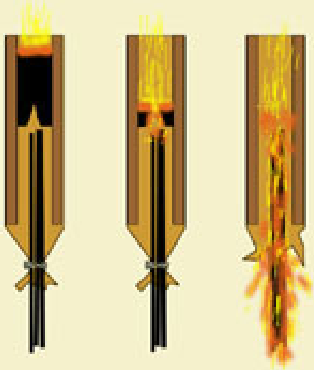

Figure 6: Improved fire transfer using the cavity.

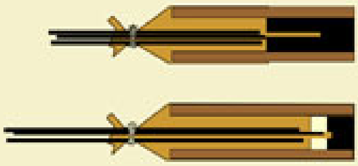

Figure 7: Two methods of avoiding blow-through when using spolettes with short delays that require small powder charges.

Improved Fire Transfer:

Figure 5 shows the use of a special spolette rammer that gives the final powder increment a conical cavity. The purpose of this cavity is to improve the fire transfer between the powder core and the black match that sits against it. Figure 6 shows the fire propagation from the end that takes fire to the end that gives fire. Note that at the point where fire breaks into the conical cavity, there is still burning comp left in the tube to keep fire directed at the match pieces. Without the cavity, only a brief burst of flame is generated at the instant the last bit of powder burns up, giving the black match less chance to ignite.

Using Small Delays:

Because spolette tubes can be any length regardless of their delay times, they are ideally suited and essential to building multi-break shells containing three or more breaks. However, as powder charges shrink below 3/4" in length, additional precautions must be taken to prevent blow-through. Figure 7 shows two methods that help prevent blow-through when using small delay charges.

The first method involves making an excessively long charge and then "drilling back" the charge on a drill press. A small hole is drilled such that it stops where the delay charge would have stopped if only the required amount of powder was used. This allows the additional support of the extra powder gripping the tube walls while still transferring fire at the instant the flame front reaches the vent hole.

The second method involves using a clay bulkhead to support the powder from behind. The clay bulkhead also has a vent hole drilled through it and slightly into the powder charge using a drill press as before. The advantage to this method is that the powder charge does not need to be rammed as hard and less powder is used. The bulkhead is rammed on top of the powder until the tube bulges out slightly, which will provide adequate support even if thin walled tubes are used. The disadvantage to this method is less fire transfer to the black match compared with the first method. It is recommended that one stick of black match be inserted all the way into the vent hole to help insure fire transfer.

More...

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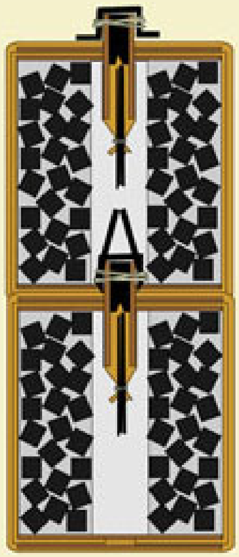
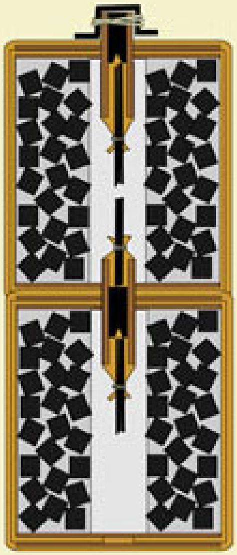
Volume 2, Issue 8

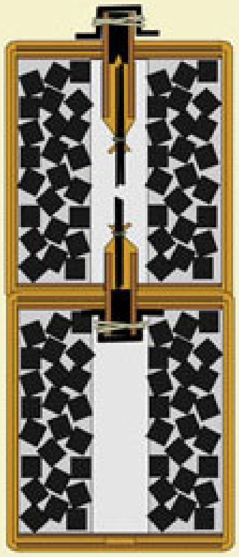
Time Fuse and Spolettes...

Spolette Orientation in Multi-Break Shells:
The following illustrations show various methods of orientating spolettes between successive breaks of a multi-break shell. Each method has it's own advantages and disadvantages, which will be discussed here. Note that the orientation for the spolette in the first break does not change regardless of how the inner spolettes are arranged.

Method 1:
The first method uses the same spolette orientation in both breaks, which is an advantage in itself since the builder has one less thing to remember. The second spolette is prepared in the usual way by scratching the powder surface and tying sticks of black match across the top. The main difference is that the black match sticks are much longer, so that they can be bent up around the top and tied together over the spolette to form a pointed "tee-pee" configuration. More twine is wrapped around the spolette to hold the bent pieces of match tightly against the side. The bottom disk of the first break has a hole that is at least 3/8" larger than the spolette diameter so that it can easily slide over the buildup of twine and match around the outside of the spolette.


Method 1


Method 2


Method 3

This first method is also the method employed by the Maltese for use in their multi-break shells, only they tie a nail or wooden stick in with the match to give it rigidity so as to avoid bending the match pieces when they are rammed into the next break.

The advantages to this method are the fact that spolettes are arranged the same on all breaks, eliminating the need to keep track of what break goes where when assembling the shells. The passfire to the second spolette is also firmly secured to the shell, allowing it to survive the forces of the first break blowing apart.

The disadvantages to this method are argued to be the sloppy fit of the first break around the spolette, which can allow hot gases to enter the first break if not properly sealed. Some builders also find that the sloppy fit makes it difficult to align the shells during assembly, although I personally find that the slop makes it easier to adjust a shell if the holes are not quite on center.

Method 2:

The second method uses a spolette that has black match tied into both ends. The idea is that the passfire match is more secure being tied in with nosing paper, and also exposes the spolette charge to more fire as the burning match gases become confined inside the tube cavity. Because the spolette holes in all disks used to make the shell are the same size, there is no need to have two different punched disks as in method 1. This also helps reduce the gaps for potential gas leaks around the bottom disk of the first break.

The disadvantage to this method is that two different types of spolettes must be made, although the top break could also be fused with the same configuration as the successive breaks with no compromise of ignition reliability. There is also the risk that, if the nosing paper burns away before the spolette ignites, then the black match could be thrown from the spinning shell. However, this drawback could be remedied by securing the black match to the spolette tube using hot glue.

Method 3:

The third method is not recommended and is shown only for completeness. While there is no real advantage to this method, there are several potential problems. The major drawback to this configuration is that the passfire into the second break is not only lacking in flame projection, it is also located at the far end of the shell. Igniting a burst charge from one end results in twice the flame propagation time compared with igniting it at the center. This effectively doubles the amount of time for the shell contents to ignite and increases the probability that the shell will rupture at one end instead of at the middle as desired. Because there is no conical cavity at the point of burn through to the inside of the second break, the chances of a misfire through failed ignition are more likely than the previous two methods.

Spolette Dimensions and Powder Charges

Shell	I.D.	O.D.	Length	Powder Charge
3" single break	5/16"	.55"	2"	1" to 1-1/4"
4" single break	5/16" to 3/8"	11/16"	3"	1-3/8"
5" single break	5/16" to 3/8"	11/16"	3"	1-3/8" to 1-1/2"
6" single break	5/16" to 3/8"	11/16"	3"	1-1/2"
8" single break	5/16" to 3/8"	11/16"	4"	1-3/4"

Since timing will vary due to factors such as ramming pressure, increment size, quality of powder etc., these numbers are a starting point for further adjustment by the worker.

Source: *Pyrotechnica IX*

The table above shows the powder charge typically used for various sized single break shells. The powder used to charge the spolettes specified here is commercial meal D. Charge sizes will vary slightly when using homemade meal.

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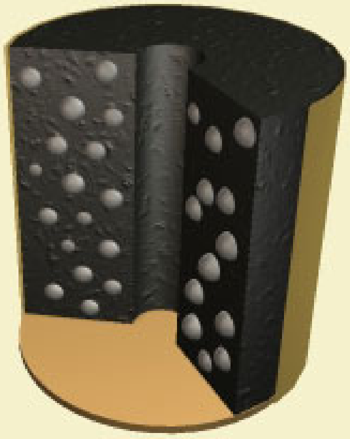
Build This...

4" Matrix Comets



Summary:
Matrix comets are simply an aggregate mixture of stars within a fast burning comet mix. The effect is to have colored micro stars streaming behind the comet head, which is usually gold so as not to distract from the colored stars.

The large size and hollow core featured in the comet described here works quite well for making attractive matrix comets.

December, 2002 Issue

Letter from the Editor:
One Year of Passfire!

Build This:
4" Matrix Comets

Tool Tip:
Build a 4" Comet Pump

Tool Tip:
A Simple Hydraulic Press

Class C Corner:
Americana, Unicorn Fountain

NEW! **ShellSim 1.0**

Comet Formula: Gold Comet
Microstars: AP Red, AP Blue, AP Green, Red Strobe, Green Strobe

Materials:

- (1) 3-1/2" disk.
- (1) 4-1/2" x 24" strip of 60lb kraft
- (10) 1" square pieces of burlap
- 2/3 cup of 1/4" round or cut stars
- 400g comet composition
- 35g water containing 5% alcohol

Tools:

- 4" comet pump with 3/4" core
- hydraulic press
- hot glue gun

Unmeasured Materials:
hot glue, 2FA, quick match, twine

Volume 2, Issue 12

4" Matrix Comets

Page 2

Introduction:
I have tried many methods of producing matrix comets. Pasted, unpasted, different sizes, different binders etc. The design described in this article has given me the best results thus far. It is based around the comet design described by Bill Ofca in his TIF Volume 7, "The 4 inch Golden Column Comet."

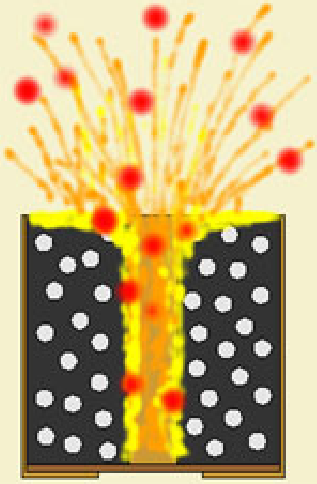


Figure 1: Flame front of a hollow comet.

Ofca's comet had a hollow core down the center, which helped increase the burn rate of the comet in order to compensate for the fact that it only burns from one end. The rest of the comet is pasted in and fitted with an end disk in order to help prevent it from cracking apart during lift.

I believe it is because of this hollow core that it performs so well as a matrix comet. While solid matrix comets seem to just drop their stars behind them in the tail, the jetting forces caused from the hollow core in these comets act as a sort of gerb that throws the stars out away from the comet (see Figure 1). Since the comet spins quite rapidly during flight, the effect is that of a bushy gold comet with stars flying out much wider than the tail itself.

Figure 2 shows the type of pump used to create this comet. For details on how to build this pump yourself from readily available materials, click here.

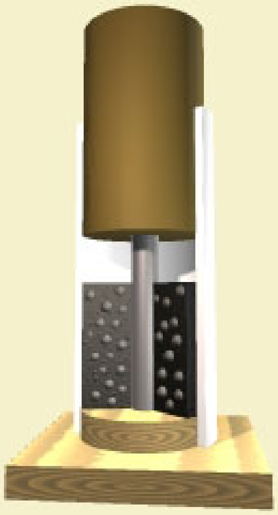


Figure 2: Comet pump component cross section.

Making the Comet Mixture:
It will take 400g of the golden comet mix referenced on the title page to make one comet. If you just want to make a solid comet with no microstars, then 500g will yield the same size comet.

Note on the formula page for the gold comet mix that it indicates to mix the KNO3, sulfur, dextrin and airfloat charcoal in a ball mill for a few hours. The remaining charcoal is mixed in by hand. I use a mesh size ranging from 30 all the way to airfloat for the remaining 16 parts of charcoal.

After the mix is prepared, dampen it using only 8% water. I like to add 5% alcohol to the water in order to break the surface tension, which helps make working the water into the composition easier. Such a small percentage of water is hard to work in, so you will just have to keep squeezing handfuls of comp until there is no longer any dust created by stirring the mixture.

Next you will want to add 2/3 cup of 1/4" stars of your choice and mix them in by hand. I prefer to use AP stars because of the pure color and longer burn time. However, you must make the effort to protect the AP stars from the nitrate in the comet mix. Failure to do this will result in wet globs that fail to ignite! Coating the AP stars with AP Prime using at least a 7% NC lacquer solution is absolutely necessary. It is not necessary to have a black powder prime on any of the stars used in this matrix comet, since the comet itself acts as the first fire.

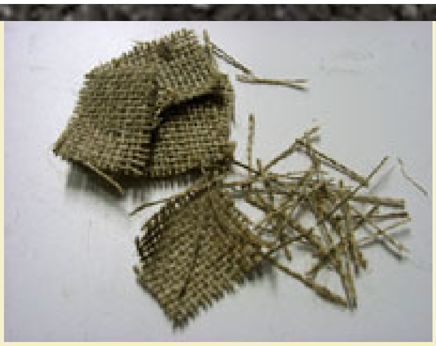


Figure 3: Squares of burlap used to provide the fiber reinforcement.

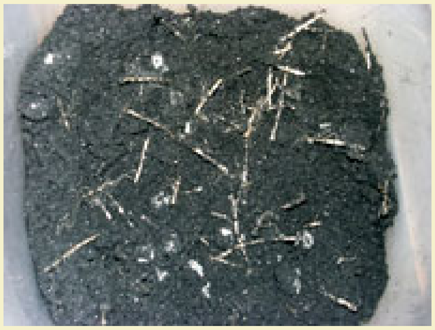


Figure 4: Comet stew! Fibers and stars mixed in and ready to pump.

Chlorate stars are to be avoided due to the sulfur present in the comet mix combined with the high pressure that will be used to press the comet. Even without the sensitivity risk, chlorate stars burn too fast and would not leave an adequate wake of microstars behind the comet.

In his booklet, Ofca describes the use of burlap fibers to both hold the comet together and provide burning embers that hang in the comets tail for an extended duration. The technique was originally employed by Legion Fireworks, a New York based manufacturer that Ofca later purchased and ran for 10 years.

I have been using the burlap fibers in all my 4" comets and have yet to see one break apart during lift. I also believe that these fibers help the comet to dry faster, as they act as channels to wick the water from the center out to the edge where some of the fibers are exposed. Despite the large mass of composition in these comets, I have been able to force dry them in a drying chamber and shoot them as soon as one week later, and never have I had a problem with them getting driven in.

Burlap can usually be found at nurserys, since it is used for potting or transporting plants. The burlap fibers are prepared by cutting a sheet of burlap into 1" squares, as shown in Figure 3. It takes 10 of these squares to make one comet. It is quite easy to pull the fibers from each square when adding them to the damp composition. Since the fibers tend to want to clump together once inside the comp, I mix the batch a little by hand after the fibers from each square are added. This will result in a better distribution of fibers compared to just adding all the fibers in one big clump and then trying to work them in.

Figure 4 shows the final mix with stars and burlap worked in.

More...

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4" Matrix Comets

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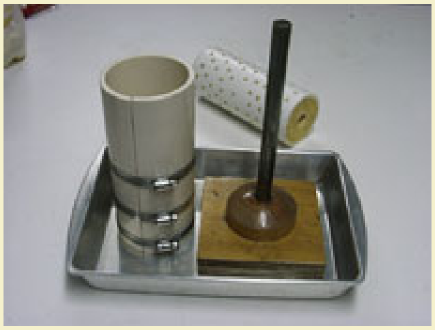

Figure 5: Loading the pump in a pan to catch spills.

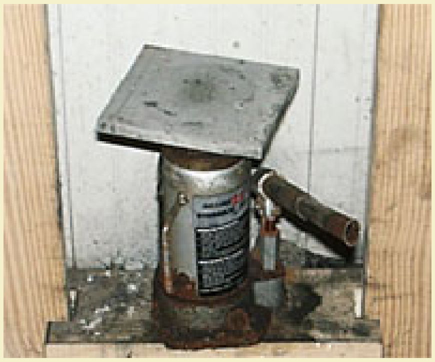

Figure 6: Metal plate on top of 12 ton bottle jack.

Pumping the Comet:
Figure 5 shows all the components of the comet pump. The sleeve is placed over the spindle and the pipe clamps are tightened down. I like to load the pump in a small pan so that any spill over is easily collected and transferred back into the sleeve afterwards. Note that the spindle shown in Figure 5 has a rounded base with a radius designed to fit a 6" ball shell. This is necessary if you wish to attach this large comet to a ball shell.

The comp will fill a 9" sleeve all the way to the top. You may even have to stuff the comp down by hand to get it all into the pipe. Once all the comp is loaded, insert the rammer and force it down as far as you can.

Because my home made comet pumps have a wooden base, it is necessary to support them from underneath using a metal plate. The plate should be thick enough that it won't bend under the pressure of your jack. Figure 6 shows a 12 ton bottle jack with the plate on it, sitting inside a home made press frame. To see how to build a frame like this one, click here.

Whatever type of press you choose to use, the top end of your rammer must be fully supported. Do not try to press against an object that only partially covers the top of your rammer or you may damage it. Use of another metal plate or a piece of wood on top can help give you the full surface contact you need.

Figure 7 shows the comet pump being pressed in the home made frame. I like to pump the jack until the plunger no longer goes down and then let the jack "dwell" under that pressure for 10 or 15 minutes. This is a good time to be preparing the next comet batch if you are making multiples. When I return a little later, I like to pump it a few more times and then wait a little bit longer before removing the pump.

When extracting your comet from the pump, first remove the pipe clamps and then twist a screwdriver blade into the sleeve gap so that it widens and can be pulled over the rammer and set aside. Next twist and remove the rammer. Gently give the comet a twist until it spins on the spindle, then carefully pull it off while being careful not to squeeze it too hard. It should look something like Figure 8 and be solid enough to handle.

If you have a drying chamber or food dehydrator, you should be able to dry this comet completely in just one week. Otherwise place it on a screen and record it's weight each day until the weight stops changing. Once it is pretty close to the weight of the components you put into it, it should be dry enough to shoot. Ofca claims it takes a month to air dry one of these, but I think a little over two weeks should do it in most cases, especially if you only used 8% moisture to wet the comp.

More...

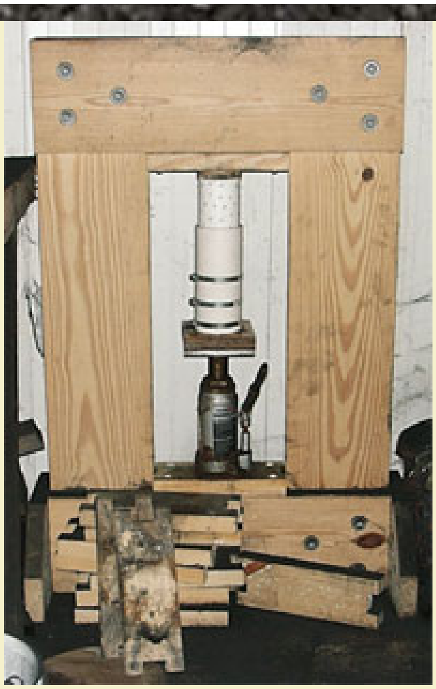

Figure 7: Pressing the comet in a home made wooden frame.

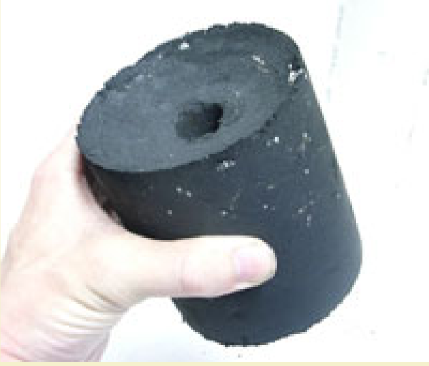

Figure 8: The finished comet ready for drying.

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4" Matrix Comets

Page 4

Finishing the Comet:

When the comet is completely dry, it should sound similar to a piece of ceramic when you thump it with your finger. You may occasionally find thin cracks around the outside of the comet if you pressed it too hard. These cracks are generally not very deep into the comet and will not effect it's performance. Since the sides of the comet will be protected by paper, fire will not be able to get into the cracks anyway. Clip off any stray pieces of burlap that may be sticking out from the sides of the comet, usually near where the pipe seam was.

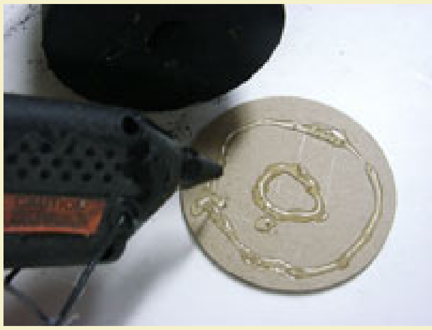

Figure 9: Hot gluing a disk to one end.

You will need to hot glue a disk onto the bottom of the comet, as seen in Figure 9. It is important to make a small circle of glue at the center where the edges of the center hole will be. This is to prevent gasses from slipping under the comet, blowing the disk off and burning from both ends at once. Thus, the glue circle must be complete with no gaps. Another circle of glue is used only to hold the disk to the comet.

The purpose of this disk is to give the lift charge a solid surface to push against, while also strengthening the comet itself. If this comet were to be mounted to a 4" canister shell, you would want to drill a 3/8" hole in the center of the disk before attaching it to the comet.

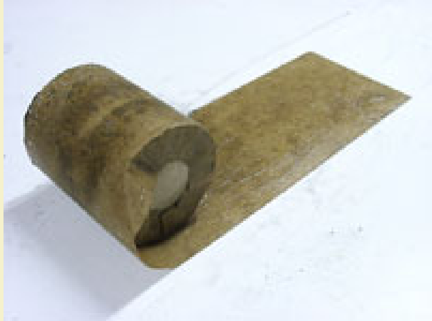

Figure 10: Pasting in the comet.

In order to further strengthen the comet and reduce the exposed surface area, it must be pasted in with a few turns of paper. I prefer to use two turns of 60 lb recycled kraft. The comet is rolled with the edge of the paper flush to one end while the other end is pleated over the end disk as seen in Figure 10. The paper is first pasted and broken in just as when pasting a shell.

When rolling the comet up in the paste wrap, be sure that there are no wrinkles or air gaps between the comet and the paper. Such gaps allow fire to propagate down the side and diminish the burn time of the comet. You want the comet to burn from one end only, as it will also be burning from the inside out due to the center bore.

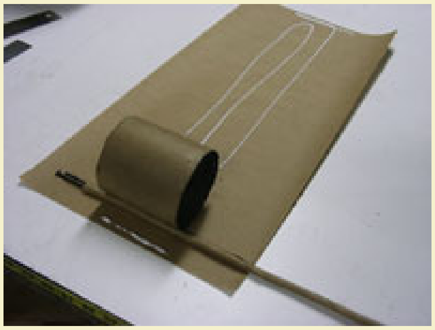

Figure 11: Lifting the comet with disk end down.

Once the paste wrap is dry, the comet is finished like a regular 4" shell. The leader runs straight to the disked bottom of the comet and it is rolled up in two turns of 30lb kraft. I like to use a few lines of white glue to help keep the kraft wrap from slipping while trying to roll it tightly around the shell, as seen in Figure 11. There is no need for a passfire to the top of the comet, as it will easily ignite from the lift gasses blowing by it. If you are concerned about this, you can always rip a small hole in your match pipe where it passes over the comet, which will blow gas and sparks into the comet as the match burns.

The comet is lifted with the standard ounce per pound rule, or 28g of lift for every 448g of comet weight. In most cases this comet will weigh about one pound so you will lift it with one ounce of 2FA. The lift and leader are tied in

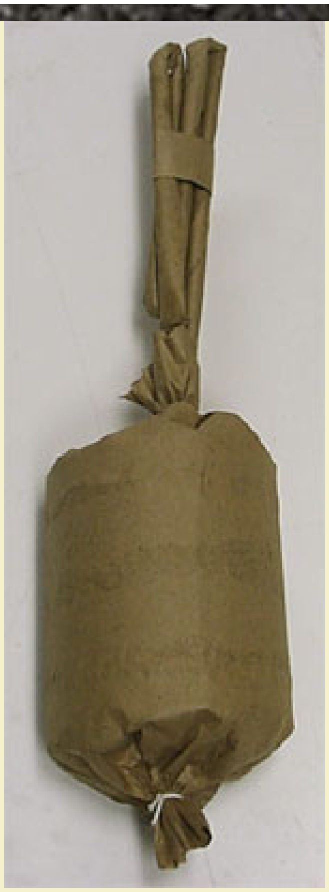

Figure 12: Finished comet looks just like a 4" shell.

with a clove hitch knot in the typical way, resulting in a finished product that looks like Figure 12.

It seems to be the general nature of matrix comets to release more microstars at the last part of their flight than at the beginning. In fact, the amount of stars seen behind the comet seems directly related to speed of travel, with higher speeds resulting in less stars.

This type of comet will leave a very thick column of smoke that can sometimes obscure the microstar tail from view if it is fired in a direction directly away from the audience. The best effect is obtained when fired at a steep angle across the audience's field of view.

Falling embers of glowing burlap fibers can make this comet somewhat of a fire hazard in dry conditions. I have also seen the burning paste wrap with end disk come down and start a fire as well. Use of this comet is not recommended in dry conditions or shoot sites near dry grass.

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Technique... **Page 1**

Attaching Large Comets to Shells

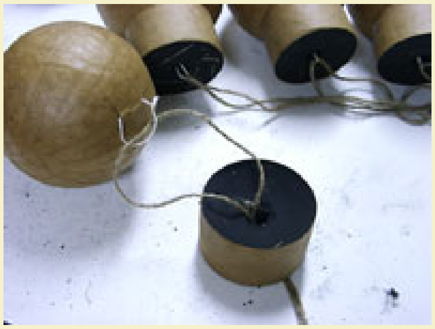


Figure 1: Running the optional lowering cord through the comet.

Introduction:
The only thing better than a BIG comet is a BIG comet with a shell attached to it! The ball shells shown here are fitted with the large 4" comets described a few months ago. To read more about making the comets themselves, click here.

The biggest hurdle to overcome in order to make these comets is the special tooling required to get the right curvature on the end of the comet that mates with the ball shell. It is important that the comet fits snugly against the shell wall in order to reduce air gaps that can cause the comet to crack from the setback during lift. Gaps around the joint will also allow the comets own flame front to work its way under the comet and jettison it from the shell during the flight, resulting in a comet going one way and the shell spinning off in some other unrelated direction.

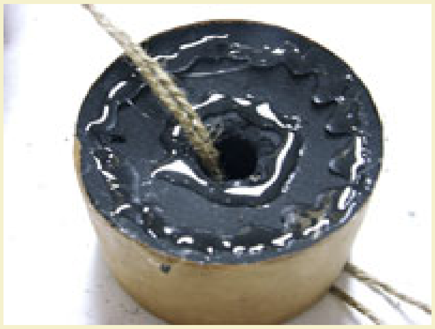
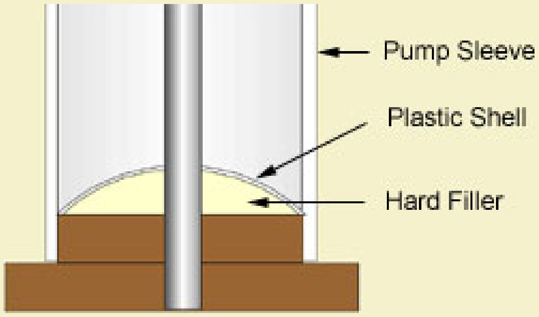


Figure 2: Applying a continuous bead of hot glue around inner and outer edge of comet where it will contact the shell.

The comet pump I made for these special comets was fabricated from wood, using a lathe to turn down a radius on the spindle base equal to the measured radius of a finished 6" ball shell. It may also be possible to get creative with some Durhams Rock Hard Putty and a plastic hemisphere for 6" shells. Try cutting out a section from the plastic shell casing so that it fits down inside your comet pump sleeve. You will have to drill a 3/4" hole dead center in the hemi section so that it can fit over the spindle. Then with the sleeve on your pump base, pour some putty into the bottom and press the plastic shell piece down on top. Push it down so the puttty fills in all the space under the plastic piece, as seen in the figure below. It should be possible to press a comet on this after it dries. There's no guarantees, since I haven't actually tried doing this myself. I'm just suggesting this as one possible do-it-yourslef method to avoid the need for a lathe.



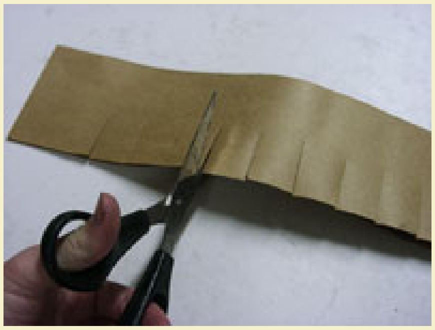


Figure 3: Cutting tabs in the paste strip before pasting.

The comets I use for this type of shell are made a little shorter than a stand alone comet, mainly to cut down on the centrifugal forces that work to rip the comet from the shell as it spins. Typically between 2.5" to 3" in height will work well. The burn time will remain constant regardless of the height due to the center bore, which sets the burn time limitation to 1-3/8" of composition (measured from the edge of the center hole to the edge of the comet). Unless you are using an unusually slow mix, the comet will always burn out before the shell breaks, assuming a time fuse duration of at least 4.5 seconds.

These comets are not finished with an end disk on one side like the stand-alone versions. They are simply pasted in on the sides only with two turns of 70lb virgin kraft.

Your shell will be a bit heavier once these comets are attached and you may wish to add some twine for lowering the shell into the mortar without ripping the shell leader. If you do this, the twine is fed through the comet prior to attachment, as seen in Figure 1.

The comet is initially fastened to the shell using hot glue, which doubles as a fastener and a sealer to prevent the flame front from working it's way under the comet. A minimum of two complete beads of hot glue are run around the inner and outer perimeter at the concave end of the comet as seen in Figure 2, then quickly press it onto the shell.

It is now necessary to secure the comet with at least two turns of pasted 70lb virgin kraft paper. Recycled kraft will not work for this application unless you use quite a few more additional turns. You really need strong paper to keep the comet from ripping lose during flight.

Figures 3, 4 and 5 show how the comet is pasted onto the shell. The dry paper strip is prepared by cutting tabs to half the paper width to allow the paper to form onto the shell. The paper is then pasted and broken in the usual way before wrapping it around the shell.

After the comet wrap has fully dried, the leader is glued up the side of the shell and comet using hot glue, as seen in Figure 6. A final few turns of 30lb kraft are glued around the comet and tied off around the time fuse to protect the exposed comet from accidental ignition.

I have never seen one of these comets fail to take fire, but if you are concerned about fire transfer you can use a paper punch to cut a small hole in the leader right where it passes over the comet. This will allow the quickmatch gasses to spray out the hole and insure ignition of the comet before the lift charge even fires.

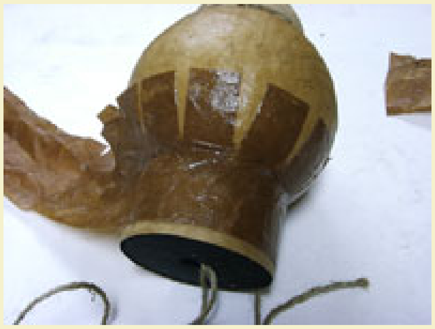


Figure 4: Rolling on two turns of the pasted 70lb virgin kraft.

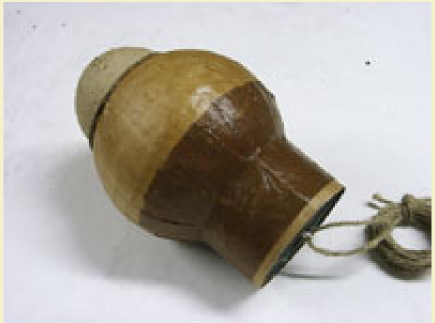


Figure 5: Finished attachment ready for drying.

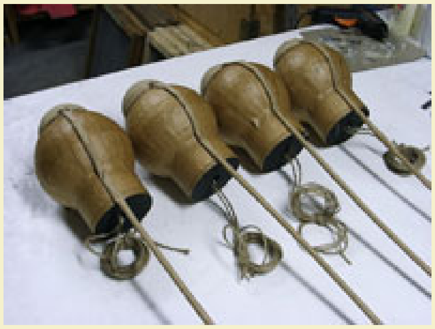


Figure 6: Hot glueing the leaders up the side of the comet.

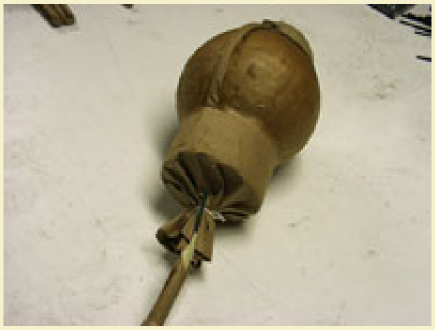


Figure 7: Finishing paper wrapped around comet and leader.

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Build This...

Materials:
(2) 7" x 1/8" thick wood slats
(1) 3/4" long segment of 5/8" dowel rod
(4) 5" long x 1/2" I.D. x 3/4" O.D. parallel wound tubes
(8) 5" long segments of 22 gauge wire
(2) 9-1/2" long segments of match pipe
(4) 10-1/2" long sticks of black match (only 2 pieces if match is thick)
(8) 3/4" pieces of 4-strand cross match type black match
(4) 5" x 3" sheets of 30lb kraft

Powdered Clay, string, slurry prime, meal powder, wood glue, aluminum tape

Compositions:
Gold 1/2" Driver, Meal, Flash

Tools:
Hammer, 1/2" flat rammer, 1/2" tapered rammer, 7/64" drill bit, wire cutters, needle nose pliers, scissors, anvil cutters.

More...

October, 2001 Issue

Build This:
Learn how to make the quad tourbillion.

Autopsy:
Take a peek inside a Lidu 6" crossing rings w/bowtie shell.

Technique:
Learn how to spike your shells with the off-center method.

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Building the 4 x Drive Tourbillion...

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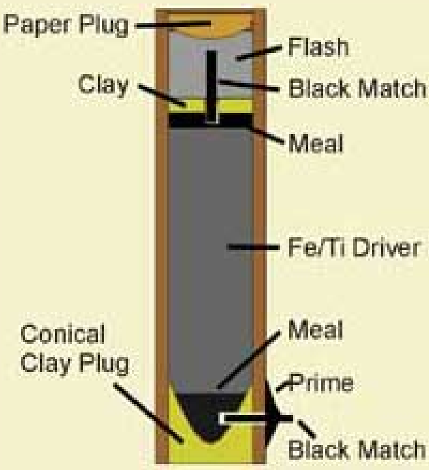

Figure 1: Driver Details

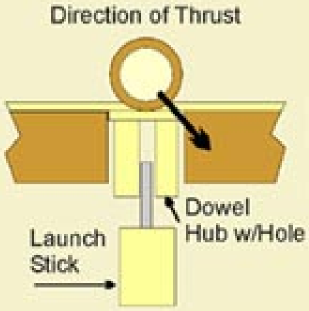

Figure 2: Exhaust Orientation

Introduction:

The quad tourbillion consists of a simple frame around which four single tourbillion drivers are arranged. They can be launched from sticks that have metal pins protruding from the end that fit into a small hole in the center of the tourbillion wheel. They may also be launched directly from the ground if the surface is smooth enough. The exhaust from each driver is positioned so that there is a 45 degree offset from the directly downward position, which enables each driver to provide both upward thrust as well as horizontal spin. The result is a thick umbrella shaped plume of sparks that slowly rise to about 100 feet in the air.

Making the Frame:

The frame for this device is made by simply gluing two 1/8" x 3/4" strips of wood that are each 7" long so that they cross at their center. I prefer to use poplar, but any dry and light wood will do. It is easiest to use a band saw to rip the strips from standard 3/4" thick stock. A 3/4" segment of 5/8" dia dowel rod is then glued on its end at the center of the hub. This is clamped and allowed to dry. If the tourbillion is to be fired from a stick, then a hole must be drilled down the center of the hub that is slightly larger than the launch pin, which is usually around 1/8" in diameter.

Loading the Drivers:

The key to successful tourbillion drivers is the use of a conical clay plug at the exhaust end of the tube. The purpose of this type of plug is to protect the exhaust hole from enlarging due to burn-through during flight, which will cause the tourbillion to slow down and even fall back to the ground. With the clay being between the paper tube wall and the burning fuel inside, burn-through is not a problem.

The conical plug is made with a special rammer that has a tapered end to it. The dimensions of this taper are not critical, so long as it produces a deep enough cavity for the exhaust hole to be protected. One issue with using tapered rammers is the increased tendancy for the bottom of the case to expand and rupture during loading. There are several methods to dealing with this problem:

- Use high quality tubes made from virgin kraft.
- Use a sleeve that clamps onto the bottom of the tube to prevent bulging.
- Use lesser quality tubes rolled in Minwax Wood Hardener to strengthen them.
- Ram the first clay increment with a flat rammer and then ram the conical plug on top of that.

Once a method of preventing end splitting has been selected, the first step is to ram in the clay plug. This should be done using a single increment of clay (fire clay or bentonite) such that there is at least 3/16" of clay between the point of the tapered rammer and the bottom of the tube. There is no need for a ramming base and the case can be loaded flat on your ramming block. It is a good idea to load the clay plug in all the tubes before charging them, since this reduces possible errors from switching between rammer types, clay and comp.

The remainder of the driver will now be rammed with a normal flat ended rammer. It is first necessary to load an increment of meal powder in order to prevent the hazard of drilling into a composition containing ferro-titanium when making the exhaust vent. The first increment of driver comp can be loaded on top of the meal before ramming. The driver comp should be rammed such that it takes about five increments to load the tube to within 1-1/2" of the top of the case. Scribing a line on your rammer at the 1-1/2" mark helps to know when the case has been loaded to the proper height.

Once the driver comp is rammed to within 1-1/2" of the top of the case, another small amount of meal is added, followed by the clay plug. Again, the meal is added to prevent drilling into the driver comp when making the passfire hole into the flash chamber. Some builders will omit the clay plug and just load lose flash over the last driver increment, but this method results in shorter and inconsistent burn times due to the powder blowing through as the flame progression nears the end of the tube. Driver comp does not grip the case walls as well as clay does, and it does not seem worth sacrificing 10% of driver burn-time for the sake of not having to ram a clay plug. Not using a clay plug will also result in the drivers not hitting their salutes at roughly the same time. The first salute that bursts will blow the frame apart and send the other drivers flying while they still burn. This is a nice effect when all drivers explode within a few seconds of each other, but not if one goes long before the others.

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Building the 4 x Drive Tourbillion...

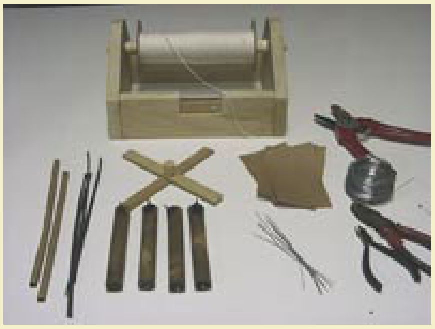

Figure 3: Ready to Assemble

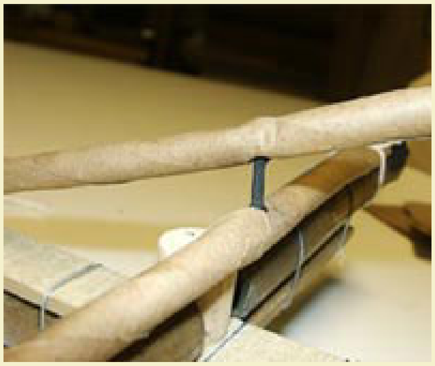

Figure 4: Quickmatch Coupling

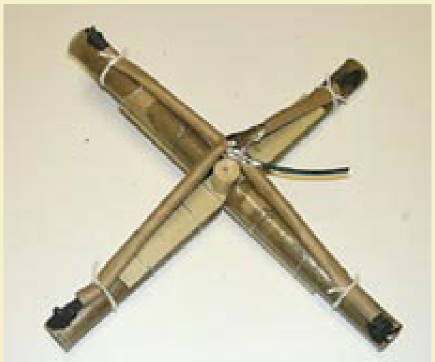

Figure 5: Completed Matching

Finishing the Drivers:
Once all four drivers are loaded and plugged, the holes for both the exhaust and passfire must be drilled. This is easiest to do with a drill press on the lowest speed setting, using a 7/64" bit for both holes. The exhaust hole should be made about 3/8" from the end of the case containing the conical plug, and should be perpendicular to the case. When drilling, you should first see powdered clay removed by the bit, followed by black powder. When drilling the passfire hole, be sure not to drill to far beyond the clay plug to avoid the risk of drilling into the Fe/Ti driver mixture.

When all holes are drilled, a piece of 3/4" black match is inserted into each one. A pair of needle nose pliers or tweezers will assist in inserting the passfire match. Next the flash chambers are filled to withing a 1/2" from the top of the case with flash powder. It may be a good idea to leave out the flash until a few trials have been conducted so that you will not risk being in close proximity of the salutes should the tourbillion fail to gain enough altitude. Once the flash is loaded, a 1/2" paper end plug is pushed into the top of the case and sealed with hot glue.

Next prepare a meal slurry to apply around the black match protruding from the exhaust hole. This is to ensure that the driver takes fire from the burst of sparks that shoot from the quick match. When the prime is dry, use anvil cutters to trim the black match down close to the level of the prime.

Attaching the Drivers:
Now that the hard part is done you are ready to put it all together. First the drivers must be attached to the frame so that the exhaust jet is facing the same direction on each arm. With the dowel rod marking the part of the frame that faces downward on launching, use the wire pieces to fasten the first two drivers so that the report ends butt up against the piece of wood that crosses the piece you are attaching them to. Be sure to angle the driver exhaust about 45 degrees from the vertical position. The next two drivers will actually go on the other side of the frame so that they can butt up against the other cross piece. Verify that all driver exhaust jets are aimed in the same direction by rotating the wheel and looking at each driver as it passes by.

Matching and Nosing the Drivers:
Place a piece of match pipe so that it reaches from one primed jet to the other across two in-line drivers. Mark the midpoint of the pipe and use a paper hole puncher to notch a hole at this point. This whole will allow the fusing between the two matches that cross over each other. Place two sticks of black match in the pipe and use a clove hitch knot to fasten it to both driver ends so that the match sticks fork around the primed fuses.

Place the remaining match pipe between the opposite driver pair and notch a

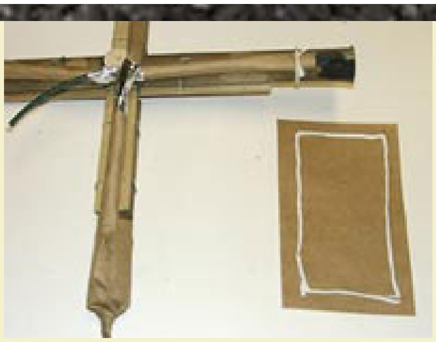
Figure 6: Applying Nosing Paper

hole where it crosses over the first hole. Insert the two match sticks and tie one end to a driver like before. Before tying to the last driver, insert a small piece of black match so that it connects between the two holes as shown in Figure 4. Also insert a piece of visco into one of the two holes at this time and secure with a piece of foil tape. Tie down the last piece of piped match and you should have something that looks like Figure 5.

The last step is to apply the nosing paper around the ends of each driver in order to protect the primed areas and provide a bucket to catch the match fire. Just over one turn of 30lb kraft is wrapped around the segment of driver that extends beyond the frame. The paper that overhangs the end of the driver is twisted like a candy wrapper to close it off, as shown in Figure 6.

At this point the tourbillion is finished and ready to fire. It may be launched by placing the dowel end down on a smooth surface like plywood or metal, or a launching stick can be made by inserting a nail or thin metal rod into the top of a 5/8" dowel rod that is inserted a few feet into the ground.

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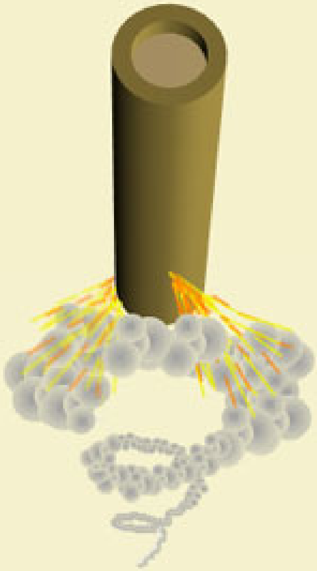
Volume 2, Issue 11

Build This...

1/2" I.D. Flying Z-Bombs.



Summary:
This fun little piece can be turned out so quickly it falls under the category of "quick pyro fix." Z-bombs are spin stabilized flying devices with salute headings. While related to the spin stabilized rockets sold under the name of Stinger Missiles, they contain no nozzle or inner core. No spindle tooling or hollow drifts are required to make them, and the finished product is nothing more than a charged tube. Unlike a buzz bomb or tourbillion, they zip up to respectable altitudes!

November, 2002 Issue

Build This:
1/2" I.D. Z-Bombs

Design Notes:
Mass Launching Z-bombs

Gallery:
4F 2002

Autopsy:
8" Ball Shell

Class C Corner:
Wild Bombardment, Starry Night

Formula: Meal powder with 6% Ti or FeTi.

Materials:

- (1) 4" or 5" long 1/2" I.D. tube with strong wall.
- (1) 3"x5" piece of 70lb kraft for star bag heading
- (1) 1-1/2" roofing nail
- (1) 4" square 3/4" thick plywood
- (1) 2" segment of 1/16" visco or chinese fuse

Tools:

- 1/2" taper tip rammer
- 1/2" flat tip rammer
- 1/2" ramming base (optional)
- 1 tsp scoop
- 1/2 tsp scoop
- 1/32" drill bit
- 9/64" drill bit

Unmeasured Materials:
powdered clay, 1/4" stars, black match, glue.

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1/2" I.D. Z-Bomb

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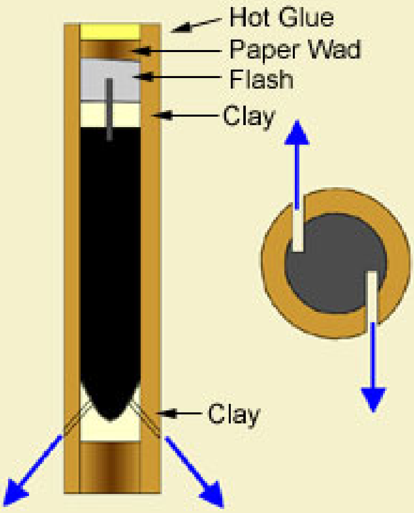

Figure 1: Side and end views of Z-bomb components and thrust vectors.

Introduction:
Z-bombs are a type of spin stabilized flying device that have no fins, no stick and no venturi. They are quite compact and unassuming at first sight, but they can fly to surprising heights. These devices are probably more related to buzz bombs or tourbillions than rockets, since they rely on spin for stability during flight. They could also be described as stinger missiles (spin stabilized rockets) without the exhaust nozzle at the bottom. In fact, simply drilling a hole into the bottom plug is all it takes to convert a completed Z-bomb into a stinger missile.

Because Z-bombs do not have a strong downward thrust vector, they ascend more gradually than the lightning bolt ascent you get from a stinger missile. They tend to accelerate faster and thus fly higher than tourbillions are capable of, and they eliminate the need for the stick or wings that tourbillions require. They also create more of a buzz sound due to the high RPMs they achieve, since they spin around their long axis the way hummers or bees do.

Two opposing exhaust holes at one end of the case utilize a compound angle to provide both the spin and the downward thrust to send the tube skyward. Figure 1 shows the basic construction of the Z-bomb, along with the thrust vectors created by the angled, off-center holes.

Like most end burning spinners that utilize a side hole as an exhaust vent, a tapered clay plug is used at the vented end in order to prevent the exhaust gases from eroding the paper tube, which will increase the hole size and progressively reduce thrust during performance. Thus, a tapered rammer is needed for ramming the bottom plug.

Figure 2 shows the two rammers required to build Z-bombs. They can be easily made from 1/2" aluminum rod available in most hardware stores. The end of one rod must be tapered using a grinder or electric sander. The taper should be about 1/2" long, and should be finish sanded with emery cloth or other fine grit to remove the rough surface of the initial grinding. Failure to do this will cause the clay to grab into the grooves and make removing the rammer from the case difficult.

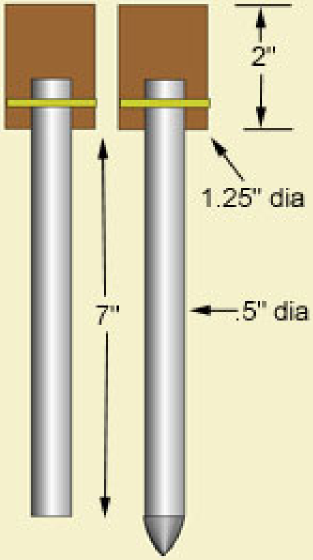

Figure 2: Home made drift set for charging Z-bombs.

The aluminum rammers may be pounded on directly with a brass hammer, but this tends to flair the heads over time. I prefer to fix segments of 1-1/4" diameter oak dowel rods to the tops as a hammering surface. This preserves your tooling and also allows you to use a regular steel hammer if you want. The wooden heads are best fixed to the rods using brass pins or nails that run completely through the wood and metal rod. The use of any type of adhesive will likely not hold up under all the pounding.

The most difficult aspect of Z-bombs is getting them to launch correctly. If just placed on the ground, they will flip over on launch 50% of the time and turn into Ground Bloom Flowers. You can launch them out of tubes, but the flight path tends to be erratic. I've seen them come out of tubes at almost 90 degree angles!

The best way to launch Z-bombs is from a special launch pin similar to how stinger missiles are fired. I have modified the traditional Z-bomb design into two versions that utilize a launch pin. The first method is easier to make, but does not work as well as the second method. The smaller diameter launch pin in method #2 allows the device to spin more freely and rarely gives problems. The fat pin used in method #1 sometimes causes the Z-bomb to bind and get stuck on the pad.

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1/2" I.D. Z-Bomb

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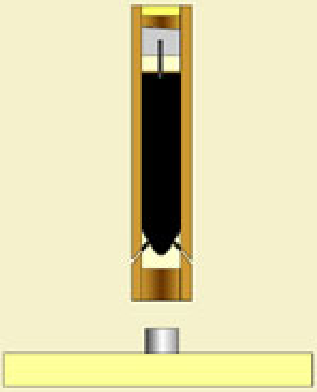

Figure 3: Launch pad and Z-bomb construction used for method #1.

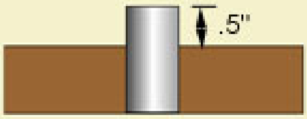

Figure 4: Raming base used for method #1.

Method #1:
The simplest launch mechanism is shown in Figure 3. The bottom plug of the Z-bomb is inset by 1/2" so that the tube can slide onto the launching base. The launch pad and the ramming base are constructed almost identically, with the launch pin being about 1/8" shorter. To make the ramming base, a 1-1/4" segment of 1/2" diameter aluminum rod is pressure fit into a 3/4" thick wooden block drilled with a 15/32" diameter hole. Similarly, the launch pad is made with a 1-1/8" segment of rod pressed into a 3/4" thick piece of wood that is at least 4" square.

A 4" long tube is placed on the base and 1 tsp of powdered clay is rammed firmly using the tapered rammer. The case is then charged in 1 tsp increments of meal. Metals such as titanium, steel or ferro titanium can be added to the meal to give a better tail. Use between 6-10% metal by weight. When using metals in the fuel, the first increment should be just plain meal, since drilling through meal with metal in it can cause a spark hazard.

Once the case is charged to about a half inch from the top, a final increment of powdered clay is rammed in place. It is important that the case be test fitted on the launch pin at this point to be sure that it can rotate freely and easily slide on and off. There is often clay caked on the inside of the tube that must be removed. Sometimes the bottom lip of the case will flair out from compression during ramming and must be reamed open again. This is easily done using a segment of 3/4" dowel with a blunt taper on one end. Failure to properly prepare the tube in this way can result in it sticking on the pin during launch.

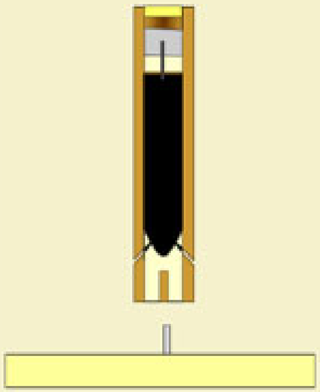

Figure 5: Launch pad and Z-bomb construction used for method #2.

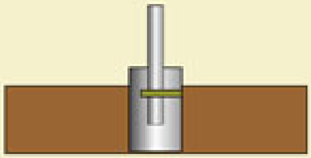

Figure 6: Raming base used for

Method #2:
The second method I devised for launching Z-bombs utilizes a smaller pin, which reduces friction and binding. This virtually eliminates problems with the Z-bomb sticking on the pad during launch. Figure 5 shows how a thick clay plug is used to create the launch pin cavity. This can be created using a special ramming base as seen in Figure 6, or the pin hole can be drilled using a drill press after the case is charged. If the hole will be drilled, then no ramming base is even required and the clay plug can be rammed flush with the end as seen in Figure 5. A 9/64" drill bit should be used if the launch pin is a 1/8" diameter nail.

Since drilling the pin hole adds an extra step, a ramming base that creates the hole is desireable. Figure 6 shows a typical home made wooden base with metal pins press fitted. The length of the 9/64" diameter pin is 1/2" above the nipple, and the 1/2" diameter nipple sticks out 1/4" above the base. Since the hole will not extend beyond the first clay increment, hollow ramming drifts are not required.

The only difference in loading this case compared with method #1 is that an method #2.

extra 1/2 tsp of clay is used for the plug, making a total of 1-1/2 tsp of clay.

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1/2" I.D. Z-Bomb

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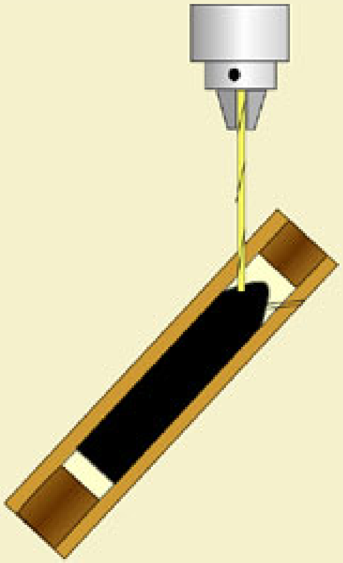

Figure 7: Free-hand drilling of exhaust vents.

Drilling Exhaust Holes:
Two 3/32" diameter holes with steep downward angles are drilled at opposing sides of the case. The need to be slightly off-center in order for the case to spin. Drilling the exhaust holes is the most critical and difficult step in making Z-bombs. The downward angle of the holes greatly effects the ascent rate and payload weight that a Z-bomb can carry.

This drilling can be done free-handed using a drill press as shown in Figure 7. The case is held with both hands at the approximate angle shown and pushed up into the spinning bit. Care must be taken to stop once the powder core is reached. You must also be careful to drill the correct end when using Method #1, since both ends will look exactly the same.

It is best to make a mark about 3/4" from the end to be drilled as the spot to begin drilling the hole. Since it is difficult to get a hole started at such a steep angle, begin by drilling slightly into the case straight on, then switch to the proper angle. This will create a dimple to keep the bit from sliding when once the case is angled down.

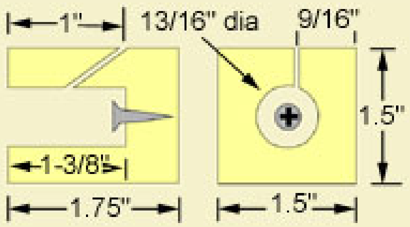

Figure 8: Guide block for drilling consistent compound angles.

I'm sure determined readers will be able to drill the holes with a hand drill if that's all that is available. Regardless of how you drill the holes, a guide block as shown in Figure 8 can help with consistent hole placement and angle. The dimensions shown are for a 3/4" O.D. case where the bottom of the powder cavity sits 3/4" from the end of the case. The screw at the back of the hole is used to fine tune the position of the hole from the end of the tube. If the hole is drilled too far up, then it can enter the powder core above the clay plug and render the conical cavity useless.

Headings:
Surprisingly, this little 1/2" I.D. Z-bomb can lift a payload of 5-8 grams of stars to a respectable height. If the heading will be stars, the Z-bomb case should be about 4" long. A salute heading should use a 5" long z-bomb case that is plugged 1" short from the top. The plugs in both types are vented with a 1/8" hole and fused with a short stick of black match.

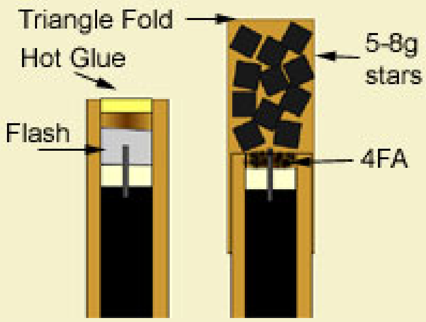

Figure 9: Salute and star headings.

Salute headings are simply charged with flash, followed by a wad of paper and sealed off with hot glue. Star headings are made by rolling two turns of 3" wide kraft paper around the end of the case so that 2" extends to form the star bag. About 1/4 tsp of 4FA black powder is poured in first, followed by some 1/4" stars. The top is folded down using a triangle fold and held down with tape or glue if necessary.

Fusing:
These devices must be fused with a very small diameter fuse such as chinese firecracker type fuse or 1/16" diameter Visco fuse. The latter may be sold by some hobby suppliers for use as cross match, but it is ideal for use with Z-

bombs (although I don't recommend it for cross-match). The fuse is inserted into either one of the exhaust holes and held in place with a piece of tape.

While no two Z-bombs will fly the same way, they generally tend to go mostly upwards. If you bent the case during ramming, you will get an amusing cork-screw pattern. Longer Z-bombs can do other unexpected things, such as making unpredictable turns. This is definitely not a close proximity item, so use with discretion!

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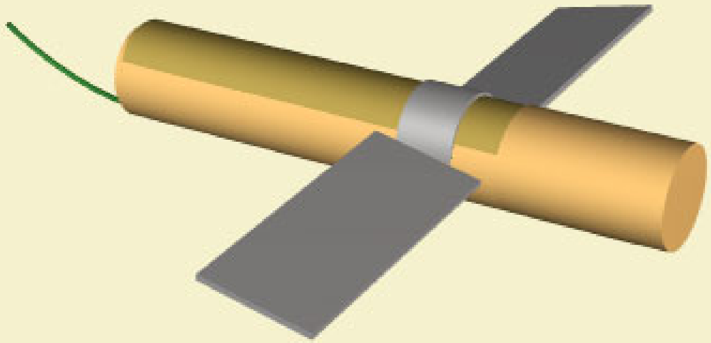
Volume 5, Issue 3

Build This...

3/4" I.D. Buzz Bomb



June, 2005 Issue

Build This:
3/4" I.D. Buzz Bomb

Technique:
Clay Rocket Nozzles

Tool Tip:
Maltese Driver Ramming Tool

Autopsy:
8" Scatter Star Shell

Class C Corner:
Alien Resurection

Summary:

Buzz bombs are a type of tourbillion that contain a single port at one end, making them easier to produce and with a longer burn time than the traditional four port tourbillions. A variety of effects can be charged into the heading of buzz bombs, with the most common being report headings. The project described here uses a glitter gerb rammed into the end, which ignites at the same time as the tourbillion lifts, creating a nice dome of glitter. Since it is not possible to create glittering drivers strong enough to lift a buzz bomb or even a four port tourbillion, this device may leave knowledgeable pyro observers a bit puzzled.

Formula: 3/4" I.D. Vertical Driver, Winokur Silver Gerb 'C'

Materials:

- (1) 40" long x 7-1/2" wide strip manila paper
- (1) 7-1/2" long x 7-1/2" wide 30 lb kraft
- Bentonite + 30% grog or ground ceramic chips 40-50m
- White glue + water 50/50
- Thin black match
- Foil tape
- Hot glue
- Aluminum flashing

Tools:

- 3/4" taper head rammer
- 3/4" flat head rammer
- brass mallet or ramming machine
- 3/4" ramming base
- 3/4" case former
- Scissors
- Hot glue gun
- Hammer & nail

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3/4" I.D. Tourbillion...

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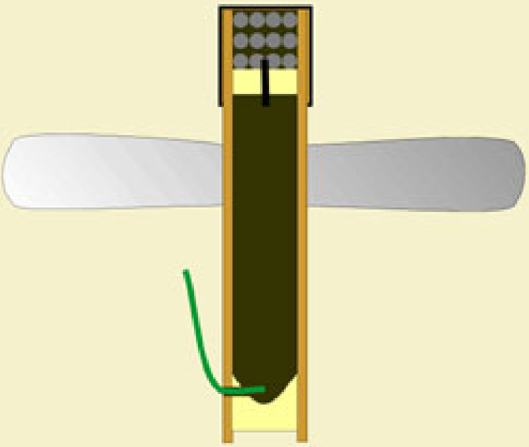

Figure 1: Internal view of a buzz bomb with star burst header.

Introduction

The Buzz Bomb is a modern version of the traditional tourbillion which has been simplified to use only a single exhaust hole. The device was actually invented in America and then later copied by the Chinese with items such as the Sunflower, Plane Flying at Night and many others.

There are two primary innovations in the buzz bomb design: the use of a conical end plug to prevent exhaust hole erosion and the use of propeller like wings to convert some of the rotary motion into upward thrust. The exhaust hole is drilled through the side of the casing toward the bottom, as seen in Figure 1. The hole must go through the clay plug as shown, which prevents the fire from burning the hole out and causing continually weaker thrust over time.

The 3/4" I.D. size shown here is actually unusually large for a buzz bomb, with 3/8" and 1/2" I.D.s being more common and easier to produce. The design is the same regardless of size, however, and the 3/8" size would be a good starting point for beginners. The fuel for the 3/8" size is simply ball milled meal with optional 5% metal dust added for different effects. The casing for a 3/8" I.D/ buzz bomb should be 3" to 4" long with a minimum wall thickness of 1/8".

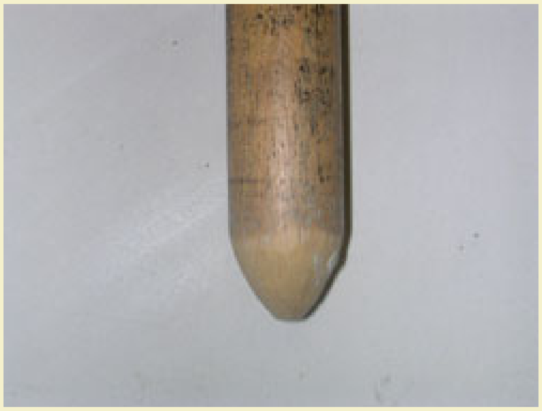

Figure 2: The tapered rammer, key to preventing exhaust hole erosion.

The larger size shown here was chosen as a companion project to go with the Maltese Driver Rammer described here. The case, end plug formula and fuel is exactly the same as that used for the horizontal girandola drivers described in that article. This way you can use one machine to produce two distinctly different types of effects.

The Tube

The first step to constructing a buzz bomb is to make or find a suitable tube that is strong enough to hold the high internal pressures and withstand the long burn time without burning through. The tube used here was made from three strips of manila file folder paper that total 40" in length. Two 14-1/2" strips plus an 11" strip that measure 7-1/2" wide were glued on one side using a mixture of water and white glue in a 50/50 ratio, then rolled around a 3/4" O.D. rod. A final two turns of 7-1/2" long x 7-1/2" wide 30 lb kraft is used to finish the casing. This will produce a final casing that is 7-1/2" long x 1-1/8" O.D. The rammer used to roll these casings was slightly over-sized in order to account for the tube ID shrinking as it dries. Both the rolling rod and the rammer were cut from the same bar in order to insure a matched size, then the diameter was increased on the rolling rod by wrapping three turns of thin plastic packing tape in parallel bands.

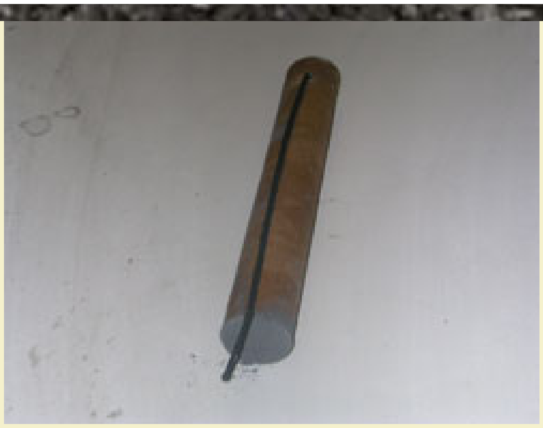

Figure 3: Passfire from ignition point to end burning color pot.

The Plug

Next you will need to create a special rammer to drive the bottom plug, which has a tapered end as shown in Figure 2. The exact angle is not important, just sand the end of a wooden dowel rod on a belt sander until it looks about like Figure 2. An aluminum rammer turned on a lathe would be even better if you are setup for doing that.

This is a high pressure driver, so you will need to use a strong end plug. The addition of a granular material such as grog or ground up ceramic shards in the 25 to 40 mesh range should be added to bentonite in a ratio of 1:3 for making the bottom plug. The top plug can be just plain old bentonite.

Start by pounding 3/4 TBSP of 1:3 grog/clay into the bottom of the tube using 10 to 12 solid hits on the tapered rammer with a brass mallet. Using rubber or plastic type mallets is inadequate and will result in blown plugs, so use a good solid non-sparking metal mallet. The plug can be rammed flush with the end of the case, but it is better if you make a small ramming base with about 1/4" of a nipple to insert the case onto. This will give your plug a better lock-in and also holds the case on center if you will be loading it using the driver ramming tool.

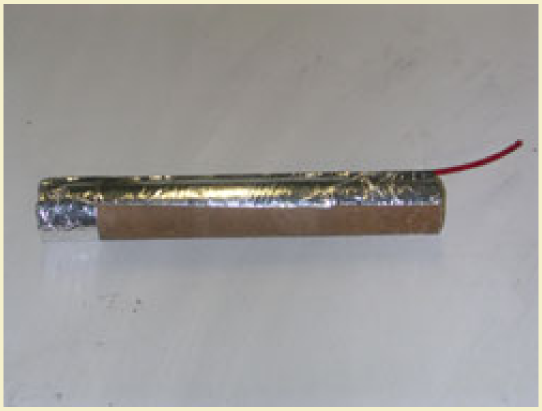

Figure 4: Foil taped used to protect passfire match.

Important: immediately after the plug is rammed, use the rammer to measure where the bottom of the plug sits so that you can mark your drilling hole. The hole needs to be about 1/16" above where the bottom of the conical cavity sits inside the tube, so it is important to measure and mark this spot on the outside of the tube so that you know exactly where it is. If you are consistent with your clay measurement and ramming force, then the hole will tend to be in the same place every time, but it is good to mark it just to be sure.

The Fuel

After the plug is rammed and marked, the fuel is charged in 1/2 TBSP increments, either by hand ramming or by using the Maltese ramming tool to considerably speed up the process. Granulating the fuel by dampening 20% with water and running through a window screen will make it much easier to work with when hand ramming, and is a necessary step when using the Maltese rammer.

Figure 5: Aluminum sheet with wing template.

The stopping point for your fuel charge will depend on the header effect you want. A final 1/2 TBSP of clay is used to plug the end, which will usually need a 1/8" passfire hole drilled through it.

The exhaust hole is now drilled at the mark you made on the side of the casing. A 3/16" hole will work well, but you may also be able to get away with an 11/64th hole to produce a little bit stronger thrust. If you blow a plug or pop the tube, drop back to the larger hole.

Because of the ceramic material in the plug, you don't want to use power when drilling through it. Drill through the case wall until you hit the clay, then turn the power off and hand twist the bit the rest of the way into the powder core.

The Header

The traditional buzz bomb heading is a report, hence the "bomb" following the "buzz." This can be made by filling about an inch of empty tube space above the end plug with flash, then closing with a wad of paper followed by hot glue. An alternate method is to insert a small hand-rolled salute into the cavity and gluing it in place, although this is a bit more work to create the same effect. In both cases you will need to drill a passfire hole through the clay end plug and insert a stick of black match into it.

This 3/4" size device actually has enough room inside the tube to load a respectable amount of small stars if you would rather make a color heading. Figure 1 shows such a heading of stars, which really don't even need a burst charge because the centrifugal force of the spinning tube will throw them out. So just leave out the burst charge and cram as many stars as you can fit into the tube!

Another type of experimental heading, which I have not worked the bugs out of yet at the time of this writing, is to charge the top portion of the tube with an alternate effect like a glitter or color pot that ignites at the same time as the buzz bomb takes flight. A stick of black match is run from the ignition point up to the top of the case as seen in Figure 3, which is then enclosed with a long piece of foil tape so that both ends ignite instantly. The idea is to have rising effects that are not easy to produce with the driver fuel, such as color, glitter, color changes and other seldom seen effects. However, some of the problems that plague this method result from the high RPMs of the spinning tube either blowing out the fire or throwing it from the tube so that the flame front is lost and the effect stops burning during flight. This paragraph will be updated when this problem is solved.

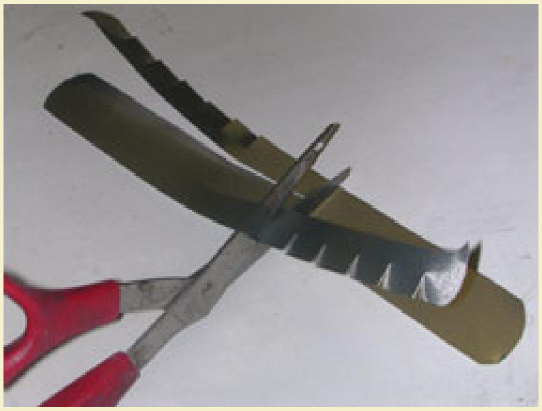
Figure 6: Slotting the tabbed support wings.

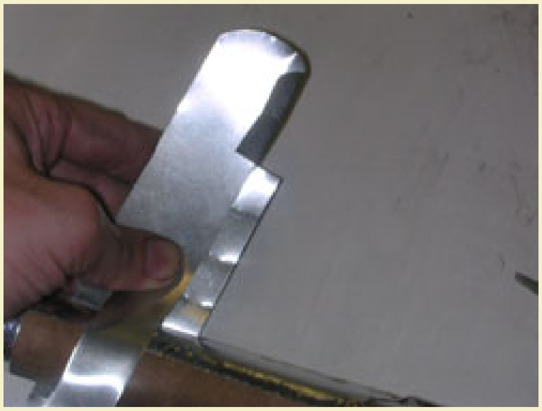
Figure 7: Folding tabs down over the leading edge of the wing.

The Wing

The original buzz bomb featured a plastic wing, while the Chinese adaptations use a paper wing. Paper wings are easy enough to produce, but they tend to be too flimsy in larger sizes such as this device. I have opted for an aluminum wing that is made using the same pattern the Chinese developed for their paper wings. It can be produced by using your computer to print this wing template pattern onto a sheet of Avery 8.5 x 11 full page size adhesive label, which will give you three patterns per sheet. You can also use an image editing program to scale this template for different size buzz bombs. You may need to scale the image anyway even for this project if it doesn't print to the correct size. Trying to get images to print at the correct size on different printers can be problematic. The distance between the wing tips measured across the length of the paper should be about 9-7/8" when scaled correctly.

The wing patterns are cut from the adhesive label and then fixed to a sheet of thin aluminum flashing. The label and the scrap of aluminum can be seen in Figure 5. This aluminum is so thin that you can cut it with scissors just like paper, using the fixed template sticker as a guide. Once cut out, the label is peeled off and discarded.

Next you will want to make a series of cuts half way through the thin strips next to each wing, as seen in Figure 6. These will form tabs that you fold over to lock the wing pieces together. The tube is weaved between the slots in the wing such that the wide cross pieces is on top (Figure 10) while the two thinner cross pieces are on the back side (Figure 11). This part can be tricky to describe, as you need to twist the wings while trying to bend the metal around the

Figure 8: Punching holes through the tabs to lock them in place.

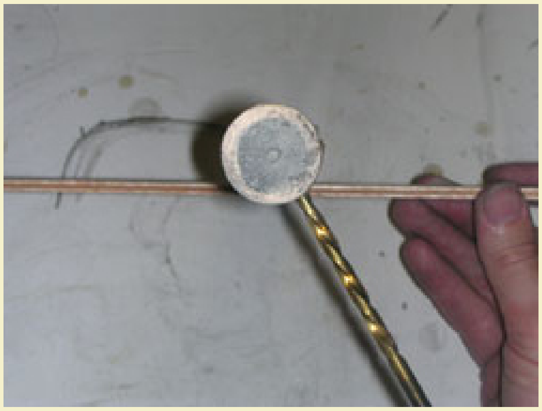

Figure 9: Proper angle of exhaust hole relative to wing plane.

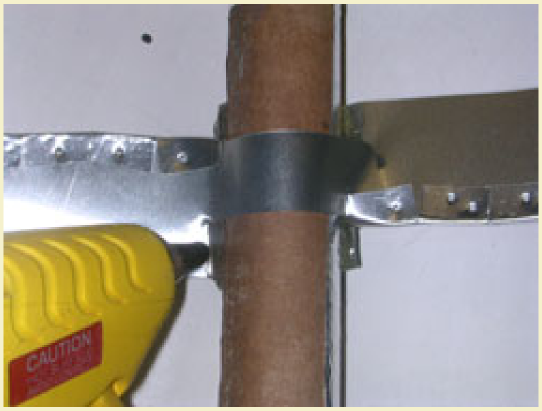

Figure 10: Gluing the wing to the engine.

driver tube, keeping the flapped pieces on the back side of each wing. When everything starts to align properly, fold the tabs over to lock the back piece to the top piece, as shown in Figure 7. If you were making a paper wing, you would use glue and staples to hold these together.

The folded tabs will not stay put without "riveting" them together as seen in Figure 8. You have to hold them in place while driving a center punch or nail through each tab so that it pins it to the underlying wing. Make sure the wing is correctly wrapped around the tube before riveting them together, since they will no longer be able to slide into place after you nail them down.

The finished wing should be twisted like a propeller such that the tabbed ends are angled upward. The casing is then rotated so that the exhaust hole will spin the tube in the correct direction to give it lift. Since the wing can also be installed "upside down" relative to the images shown here, it is important to pay attention to the desired direction of rotation. For the orientation shown in Figure 10, the tube will need to spin clockwise. If your riveted edges are reversed from that in Figure 10, it will need to spin counter clockwise.

The last step is to hot glue your wing to the engine, which is done by squirting hot glue into the cracks along the edges as seen in Figure 10. Before applying the glue, the engine will need to be properly rotated so that the exhaust hole is angled down at 45 degrees to the horizon, as seen in Figure 9. This way the engine provides both spin and downward thrust to aid with flight. If fact, the buzz bomb will still fly with just a straight stick attached in place of a wing, as seen in Figure 9. However, it will not fly very high and will tend to drift sideways a considerable distance. Given that this is basically a flame throwing buzz saw flying around without a blade guard, it is very preferable that it goes straight up rather than coming after you!

Usage

Buzz bombs are placed flat on a smooth surface with the exhaust hole facing down. They can be launched from asphalt, but usually not grass or bumpy turf that prevents them from spinning well. A good clearing is required as the flight path is often unpredictable, just like their big brother-- the girandola!

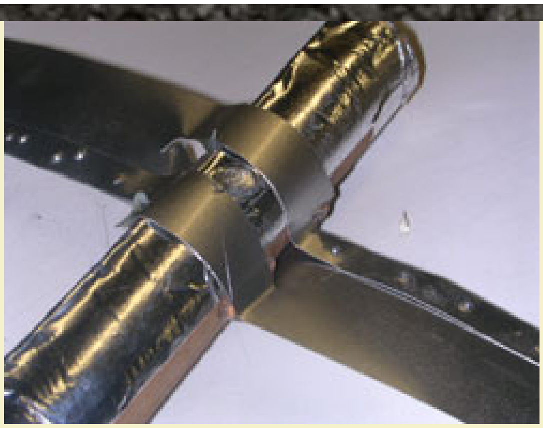

Figure 11: Bottom view of the wing.

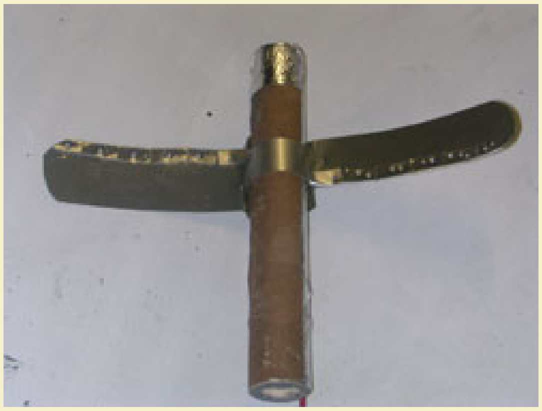

Figure 12: The completed buzz bomb.

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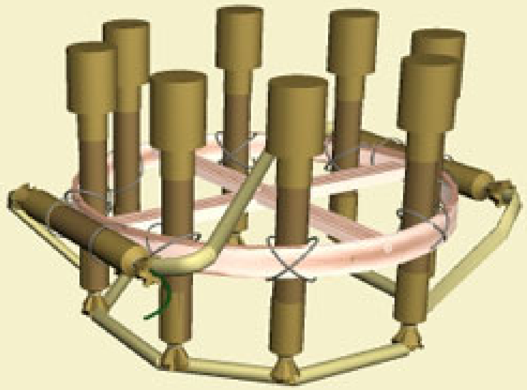
Volume 2, Issue 7

Build This...

12" Girandola



July, 2002 Issue

Build This:
12" Girandola

Design Notes:
Girandola Design

Tool Tip:
Building Girandola Frames

Autopsy:
6" Smiley Face Pattern Shell

Summary:
This small girandola is a good entry point for learning how to make these flying wheels. The design shown here starts with two horizontal drivers that spin the wheel for about six seconds, after which a delay element ignites a ring of eight drivers. The wheel will then ascend to about 300 feet while the horizontal drivers continue to throw out an umbrella of sparks. The show finishes when the eight individual headers burst with a display of stars.

Prerequisite Projects: Three Stage Triangle Wheel
Prerequisite Reading: Girandola Design, Building Frames, Fire Retardant Match Pipe

Formulas: 1/2" Vertical Driver, 1/2" Horizontal Driver

Materials:

- (1) 12" diameter frame weighing under 100g
- (10) 5" long 1/2" I.D. x 3/4" O.D. kraft tubes
- (10) 3"x5" strips 30 lb kraft (nosings)
- (8) 3"x12" strips 60 lb kraft (headers)
- (20) 5-1/2" lengths of 18 gauge wire
- (2) 36" pieces of 3/8" ID fire resistant match pipe
- (1) 3-1/4" length Chinese time fuse
- (1) 4" long visco

Tools:

- 1/2" Ramming Base
- 1/2" Ramming Drift
- Non-sparking hammer
- Wire cutters
- Hot glue gun
- Scissors
- Pliers
- Paper hole puncher
- Scale
- 7/64" drill bit
- 1/8" drill bit

Unmeasured Materials:
White glue, bentonite, grog, black match, 4FA, stars, string, foil tape.

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12" Girandola...

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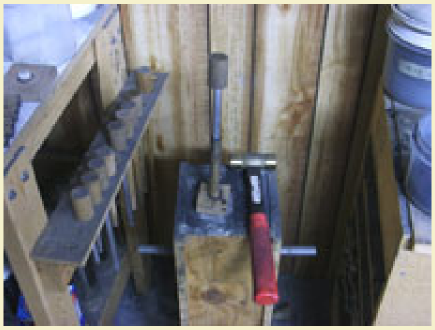

Figure 1: Loading the drivers on a pounding block.

Making the Drivers:
The drivers used in most girandolas are black powder end burners with no cavity in the powder charge. This is due to the desire for the longest burning driver possible while still having enough thrust to do the job. The duration/thrust tradeoff is very important to dial in when developing your drivers.

That's right, you will have to do some testing on these drivers even though the formulas are specified here. Black powder drivers of this type are very demanding creatures and it isn't as simple as mixing the formula and loading it into a tube. I wish it was, but there are too many variables such as mill times, charcoal types, ramming pressure and other issues that will give you different results than my own. The formula given is a good starting point, but you will most likely have to modify it. For a better understanding on how to go about this process, read thrust calculation section in this months Design Notes article.

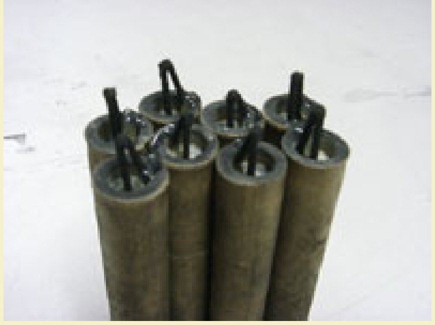

Figure 2: Drivers fuses held in place with hot glue.

You will need to produce a vertical driver that burns for at least 6 seconds and has about 200 grams of thrust, or capable of lifting a 35g stick (depending on your thrust measurement preference). This amount of thrust will blow out the cheaper varieties of recycled kraft tubes, so you may want to treat your tubes with Minwax Wood Hardener if this presents a problem.

The horizontal drivers should burn about 12 seconds. These will be under much less pressure, so there should be no risk of blowing these out. In the event that your driver burns longer than 12 seconds you can simply increase the time fuse delay that controls when the vertical drivers ignite (see page 4) such that the duration of the vertical drivers will match the remaining duration of the horizontal drivers at the time of liftoff.

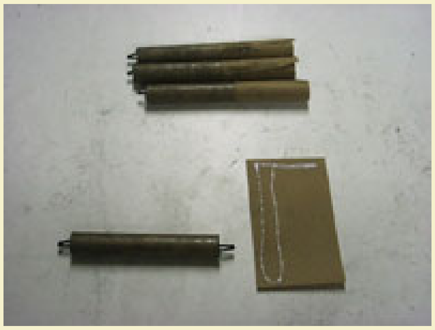

Figure 3: Rolling on the nosing paper.

Do not proceed to make all drivers until these specifications have been dialed in! If you can't get the thrust, then lower the charcoal content. If you have a lot of thrust but short duration, then raise the charcoal content. It helps to start by screening charcoal with ball milled meal in progressively larger amounts, making and testing a short driver with each new combination. Once you get an acceptable driver, then ball mill the final formula (without the metal added of course) to ensure a consistent and intimate mixture and test one last time.

The tooling for making these drivers can be made as described here, except the ramming base will only have a small pin just long enough to mark the center point in the clay plug. Since there is no cavity, only a single solid ramming drift is required.

The basics of loading this type of driver can be found here. Figure 1 to the left shows a driver being loaded on a ramming block, which was made by filling a

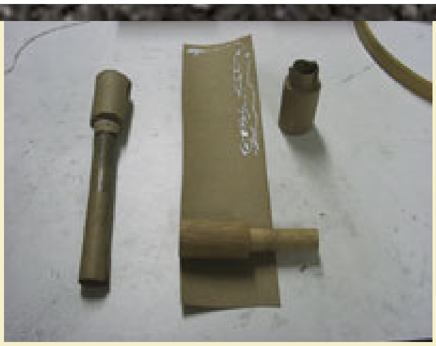

Figure 4: Using a former to make star bag headers.

2ft tall plywood box with concrete. It is important that a solid, vibration free path be created from the hammer surface to the rammer, through the case and spindle all the way to the ground. The use of rubber mallets, plastic hammers or other lightweight, shock absorbing materials is not recommended. Avoid ramming on anything other than a solid concrete floor or hard soil. Even when ramming on hard soil, at least two feet of solid material such as thick timber or concrete should be between the ramming base and the ground.

You will need to ram eight vertical drivers and two horizontal drivers. The vent holes of the vertical drivers are hand tapped with a 7/64" bit using a drill press to apply pressure to the bit while twisting the chuck by hand. Care should be taken to stop drilling once the powder has been reached, as too deep a cavity in the powder charge can cause the driver to over pressurize and blow. The top plug of all vertical drivers will also need to have a passfire hole drilled through the plug. Both horizontal drivers will get a 1/8" vent hole, but no passfire hole is necessary on the other end.

A bent piece of black match is hot glued into both holes on all drivers, as seen in Figure 2. This insures that the passfire into the small, shallow holes will not pull free during transportation and launch.

Scraps of 3"x5" 30lb kraft are rolled around the exhaust end of all the drivers. Figure 3 shows the glue pattern for applying the nosing paper.

Star bags for the top end of the vertical drivers are created by rolling a 3" x 12" piece of 60lb kraft around a special former shown in Figure 4. This former consists of a 2" long segment of 1-1/4" dowel rod that has another 2" long segment of 3/4" dowel rod glued into one end. The paper is rolled flush with the flat end of the larger former, then the overhang is crimped down around the smaller dowel to form a sleeve that fits nicely onto the 3/4" O.D. driver. Glue is applied around the top of the driver before inserting the star bag, then a clove hitch is used to secure the flange onto the driver.

More...

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12" Girandola...

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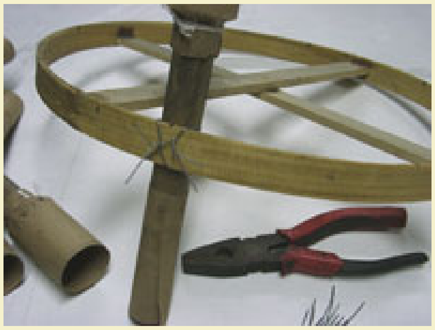

Figure 5: Wiring drivers to frame.

Assembly:
Once all drivers are nosed and the star bags are attached, they are ready to be wired onto the frame. Since this is a single hoop style frame, wire must be used to hold the drivers to the frame. If twine is to be used, the drivers must first be glued onto the frame using hot glue. Otherwise the vertical drivers will wiggle if only string is used. If twine is used, the best variety is the waxed linen twine sold by pyrosupplies.com. The wax will help prevent the driver from sliding upwards during flight and also make cinching knots easier during assembly.

The advantage to using wire is that the drivers can be easily cut from the frame after use. Wire is also faster to apply than string. When using wire, use two pieces per driver so that they cross each other in an X pattern, as seen in Figure 5. Snub nose pliers are used to tighten down the wire by twisting, and then wire cutters are used to cut the excess. Galvanized steel wire is preferred, but copper will also work if you are worried about a spark hazard when cutting the wires. It is a good idea to attach all the wires and then cut them all at once outside on the remote chance that you do create a spark.

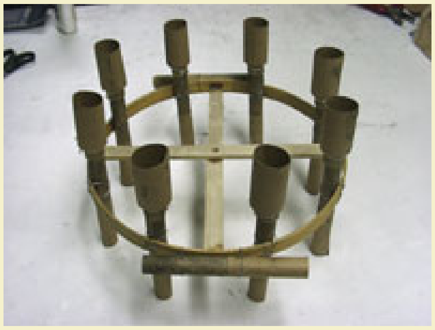

Figure 6: All drivers wired in place prior to fusing.

When all the drivers are wired in place, you should have something that looks like Figure 6. It is a good idea to weigh your girandola at this point so that you can estimate your maximum payload. This will give you your flying weight minus the header contents. If you have measured the thrust for your vertical drivers, multiply this value by eight to figure your total thrust. Now divide that number by two (for a slow rising girandola) or two and a half (for a fast rising girandola) and that will be your ideal weight. Hopfully this weight will be at least 100 grams more than the weight of your girandola you just measured. The difference between the ideal weight and the weight you measured is now divided by eight to give you the recommended payload for each header. The stars will be loaded last, so remember this payload calculation.

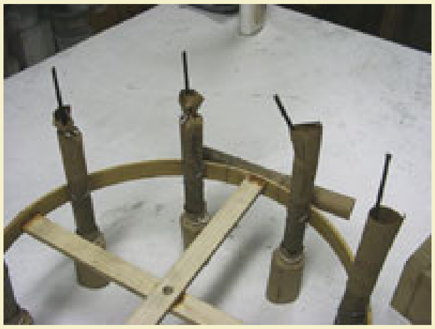

Figure 7: Sticks of black match tied into driver nosings.

Fusing:
Flip the girandola upside down and begin the fusing process by inserting a stick of black match into each of the vertical drivers. At least one inch of match should protrude when the nosing is cinched around the match with a clove hitch knot, as seen in figure 7.

Next you will create the ignition ring using a 36" piece of 3/8" I.D. match pipe. It is important that this match be made fire resistant (see article on Tard Match) so that the drivers do not ignite prematurely from the horizontal driver sparks.

First bend the length of pipe around all the drivers and mark where the fuses will intersect. The two ends of the pipe should meet at the midpoint between any two drivers. A hole will need to be cut at each of these marks using a

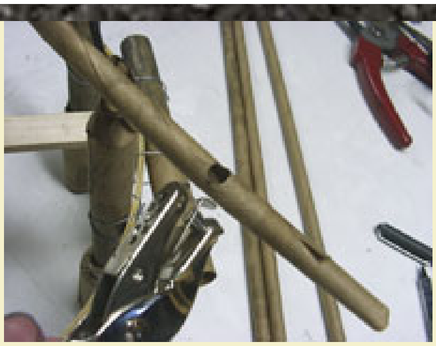

Figure 8: Using a paper punch to make holes in match pipe.

paper punch, as seen in Figure 8. The punch is used to pinch the side of the pipe and cut half a hole, which then unfolds to make a full size hole. Make sure all the holes are aligned on the same side of the pipe.

After all the holes are punched, two sticks of black match are fed into the perforated pipe such that they protrude about an inch from each end. The pipe is now connected to each driver by sliding the pieces of match extending from the drivers into the holes in the pipe. Figure 9 shows this procedure half way completed.

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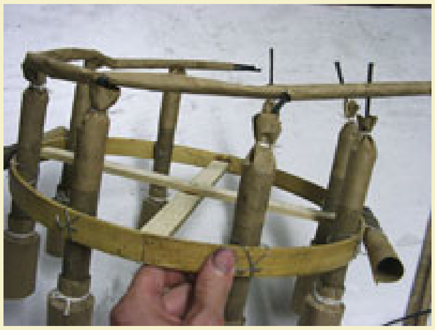

Figure 9: Inserting match sticks into ignition ring.

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12" Girandola...

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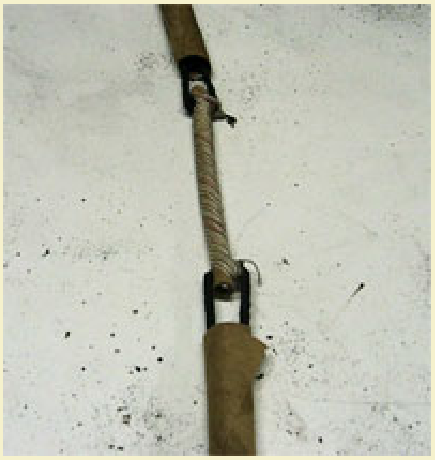

Figure 10: Adding time fuse delay into quickmatch link.

Once the ignition ring has been installed full circle, the two ends are fed into each other and sealed with a piece of foil tape wrapped around the junction. The junction where each driver connects with the ignition ring is now protected with a piece of foil tape. The tape is applied from the base of the driver, over the top of the ignition ring, then back down to the base of the driver on the other side. Make sure there are no gaps around the edges of the tape where sparks could reach the black match junction.

Next prepare a piece of pipe that is long enough to connect both horizontal drivers together. Two sticks of black match are again placed inside so that about 3/4" sticks out from both ends. The protruding pieces of match are folded over against the side of the pipe to form a hook, thus preventing the pipe from being pulled out of the nosing accidentally.

Tie one end of the pipe into one of the horizontal drivers, then place the other piece into the other driver but do not tie it in yet.

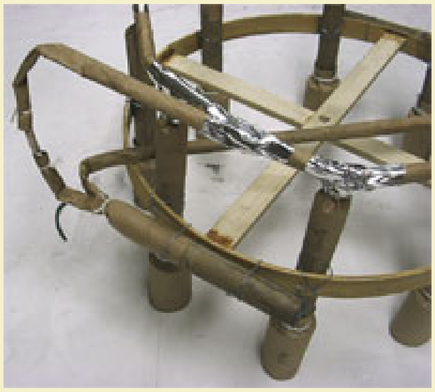

Figure 11: Driver nosing ties in visco, delay link and passfire to other driver.

Delay Fuse:
Next you will need to build the passfire to the ignition ring, which contains a delay fuse that burns for about six seconds. Using a 3-1/4" long piece of Chinese time fuse, punch and cross match with a 12" piece of black match at 1/4" from each end. Cut two 6" pieces of match pipe and slide them onto both sides of the delay link, as shown in Figure 10. Allow the pipe to extend over the time fuse by about an inch on each side, then secure it in place with some twine. Two strands of cross match should be extending about an inch from the ends of both pipes.

This delay fuse will connect from the driver to the ignition ring, as seen in Figure 11. Use the paper punch again to punch the junction hole in the side of the ignition ring. Insert the bare match from the delay link into the ignition ring and seal the junction with a few turns of foil tape. The other end is routed into the driver nosing that also contains the passfire to the other driver. Finally, a 4" piece of visco is inserted with the other two pipes and the nosing is firmly closed with twine.

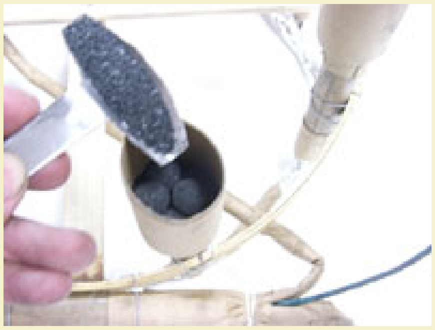

Figure 12: Adding small scoop of 4FA to star bags containing 3/8"

Loading the Headers:
Finally you are ready to load the headers. If you have strong drivers you may be able to load as much as 20 or 25 grams of stars into each one. If your drivers are not as strong and your payload is limited, you can use a lighter type of star such as firefly or aluminum flitter.

This type of heading is not a shell burst, rather it is more like a mine. Thus, only a small amount of 4FA is poured into each header to pop them open. Once the burst charge is loaded, the excess paper on top of each header is triangle folded and held down with a piece of foil tape.

round stars.

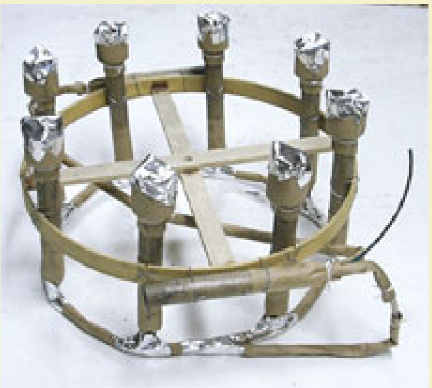

Figure 13: Completed girandola with foil protection covering star bags.

It is not a bad idea to cover the entire header with foil tape in order to protect the rather thin case from accidental burn-throughs that will fire your driver backwards and ruin the girandola. I have seen very elaborate girandolas crash and burn from this type of malfunction, so it is time well spent.

After all your hard work, you should have something that looks like Figure 13. You should also have an irresistible urge to fire your new creation immediately! But first, read these tips on building a launch stick.

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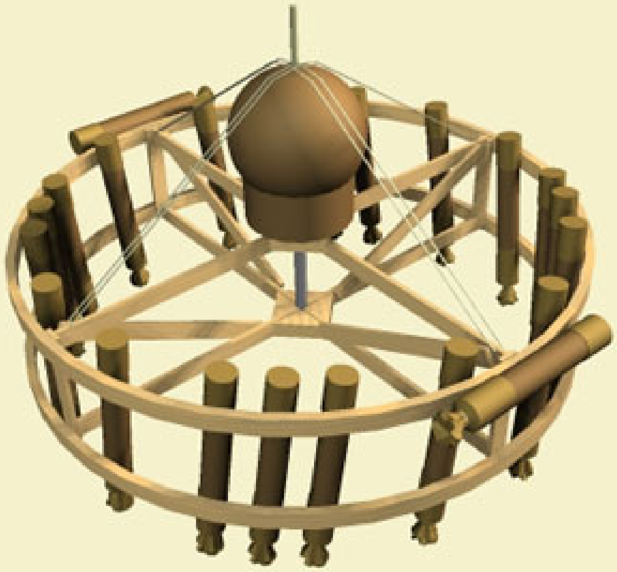
Volume 5, Issue 4

Build This...

24" Girandola w/6" Header



September, 2005 Issue

Build This:
24" Girandola

Technique:
Large Girandola Frames

Technique:
Clove Hitch Knots

Tool Tip:
String Dispenser

Autopsy:
10" Double Petal Ball Shell

Summary:

This award winning girandola uses 20 vertical drivers to lift a heavy-duty six inch double petal ball shell up several hundred feet, crowning a graceful ascent with an unexpectedly large header effect. While the frame is a respectable 2 feet in diameter, the illusion of a much larger frame is created by using a ring of 16 tethered lances that swing out on three foot long strings. For those who witnessed this beast at the 2005 PGI convention, the pictures used in this article depict the construction of the actual girandola that was used in competition, as does the companion article which shows how to build the frame.

Prerequisites: 12" Girandola, Maltese Driver Rammer, 6" Double Petal Shell

Formulas: 3/4" I.D. Vertical Driver, Winokur Silver Gerb 'C'

Materials:

- 24" double ring girandola frame weighing about 450g or less
- (20) 3/4" I.D. vertical drivers, 9 second burn time, 500g thrust
- (2) 3/4" I.D. horizontal drivers, 6 second burn time
- (2) 3/4" I.D. horizontal drivers, 9 second burn time
- (4) 5/8" I.D. silver gerbs, 9 second burn time
- (16) 3/8" I.D. green lances, 15 second burn time
- (1) 6" ball shell, 10 sec time fuse
- (12) 3 foot long internally foiled quickmatch pipes
- (40) feet of black match
- (16) strands of 3 foot long flax or hemp twine
- (48) strands of 22" long waxed linen twine
- (24) sheets of 7-1/2" x 4" wide 30 lb kraft (driver nosings)

Tools:

- Hot glue gun
- Knife
- Rubber band
- Paper hole puncher
- 5" case former
- Girandola stand
- White glue
- Foil tape

- (4) sheets of 6-3/4" x 3" wide 30 lb kraft (gerb nosings)
- (16) sheets 3" x 2-1/2" wide 30 lb kraft (lance nosings)
- (2) 4-1/2" diameter chipboard disks
- (2) 24" long x 3-1/2" wide poster board strips
- (1) 29" long x 4" wide 60 lb recycled kraft strip

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Volume 5, Issue 4

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24" Girandola...

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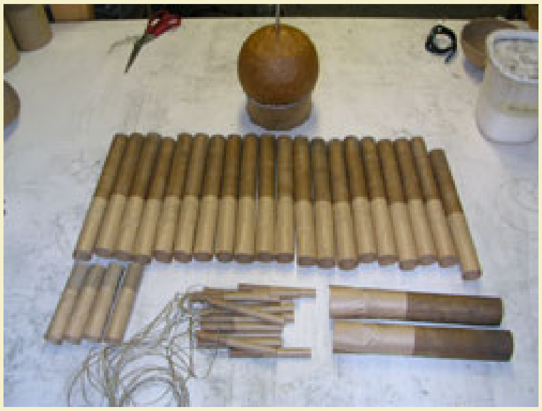


Figure 1: Completed components required to build the girandola.

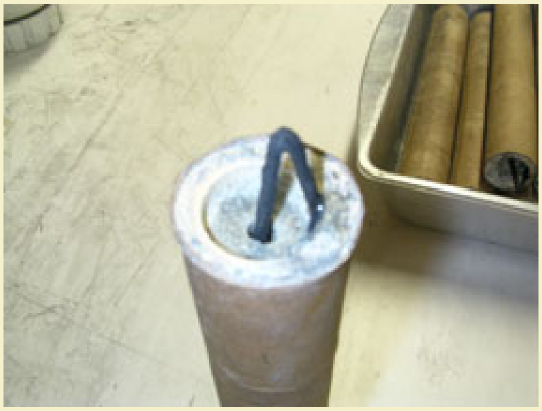


Figure 2: Matching the drivers with a hooked stick of black match secured by a dab of hot glue.

Introduction

The bigger a girandola gets, the more toys it can take along for the ride. A 24" girandola can easily lift two or three pounds of payload in addition to it's own weight, which gives you a lot of options for creative effects. Not only can you increase the size or number of traditional headers fastened to the drivers, you can lift rising gerb effects, second stage mini-girandolas, parachutes, lance work attached to the frame or even separate lance work suspended below the girandola as it rises.

The girandola described here replaces the traditional driver mounted headers with one large central header. This will give you a more impressive looking header compared with the many small puffs of stars that seldom occur simultaneously using the traditional method. Keeping the header effects detached from the drivers has several advantages. A driver blow-through will not prematurely set off a header on the ground or on the way up- a defect that is often seen with the traditional method. On the flip side, thin walled star-bag type headers that are prone to accidental ignition when horizontal driver sparks work their way into the casing will not set off the underlying driver, causing it to burn backwards or from both ends (thus reducing thrust). Timing is also much easier to control with a single detached header if the effect you want is a single burst of stars that distribute equally in all directions. Trying to achieve that using multiple headers attached to the drivers relies on the unlikely combination of ramming all drivers to the exact same burn time in addition to igniting them all at the exact same time in order to achieve a uniform ring of headers that all break at the same time. Lastly, it is also less work to create one 6" shell than it is to create eight 3" shells, and the payload weight is about the same.

In addition to a nice header, this girandola also features a unique rising ring effect that employs sixteen lances suspended on threads attached around the perimeter of the frame. When the frame is spinning at a good clip, the individual lances will visually blend into one continuous ring of light surrounding the central frame. I have been using this effective trick for years and find it surprising that it hasn't caught on more in popularity, since it is simple to achieve and can be applied to any size girandola. The effect creates the illusion of a much larger frame than what is really there, and the additional weight required to produce it is minimal. Many variations can also be made, such as double rings, color changing rings, waterfall rings etc. For this project we are just using a single green ring.

A group of four downward pointing silver gerbs are also used to give a rising tail effect. I prefer to use a no-frills black powder driver for all girandolas, since the Maltese driver rammer tool can not be used

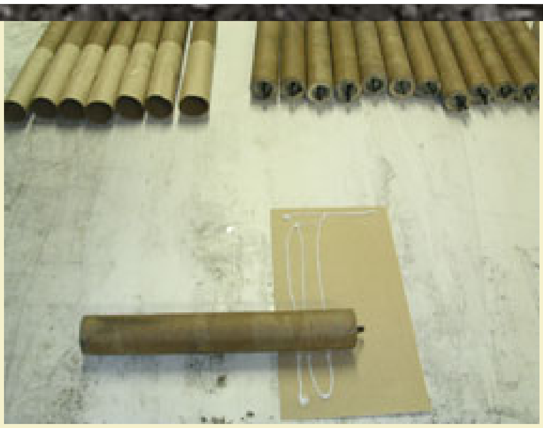


Figure 3: Nosing the drivers after fusing.

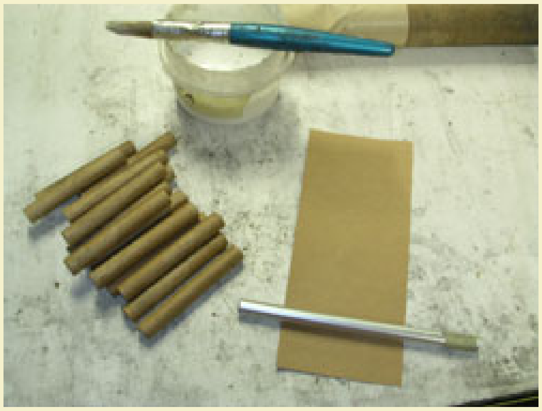


Figure 4: Dry rolling the lance tubes on a 3/8" former.

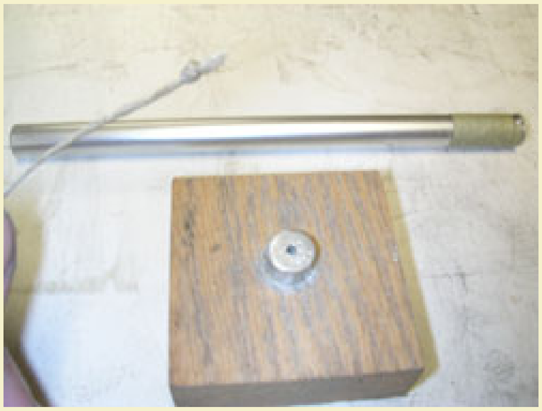
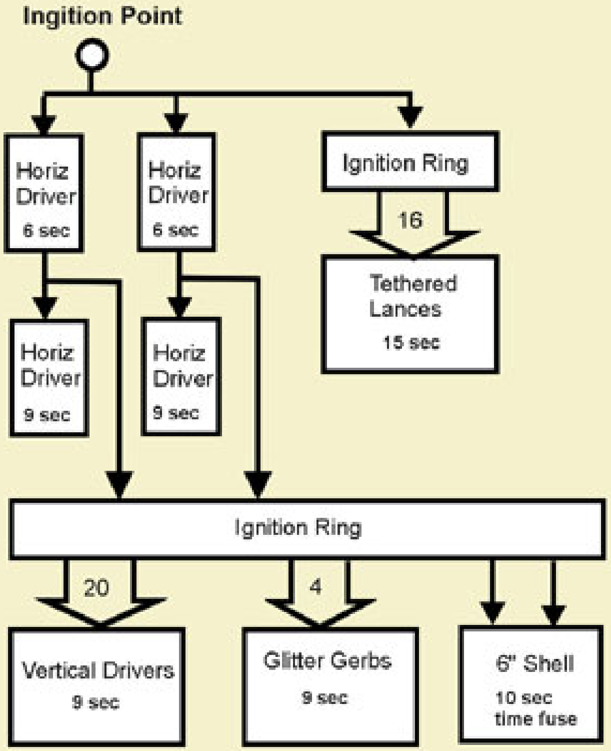


Figure 5: Tooling for securing twine into bottom of lances.

with metal dust anyway. This way I can get the driver dialed in and never mess with the formula again, then use rising gerb effects to create whatever tail effect I want.

Components

The first phase of girandola construction consists of building all the individual devices that will be attached to the frame. Sometimes this can be like building a small show, depending on the size of your girandola. The most tedious part is by far the large number of drivers that must be loaded. Figure 1 shows all the components required to build this project. Note that there are two 1-1/4" horizontal drivers in this picture, while the recommended design is to use four 3/4" horizontal drivers instead and fire them in pairs as shown in the fusing diagram below. Trying to use one pair of horizontal drivers that burn for 15 seconds tends not to generate enough thrust to get the girandola spinning good before it takes flight. The lance ring, which swings out to a radius of four feet from the center point of the frame, will add considerable resistance to rotation which requires a stronger horizontal driver than usual.



Note in the fusing diagram that the time fuse on the header shell does not take fire until the drivers fire. If the shell were to take fire at the initial ignition point, there would be a hazard to bystanders if a fusing error or defect caused the driver ring not to ignite. You don't want the shell to ignite until you know the girandola is going to fly, or at least TRY to fly!

The drivers used for this project are produced exactly as described in the Maltese Driver Rammer article. If the drivers are produced by hand ramming, they will only burn about 7 seconds. This is not long enough to get the 6" shell to a good height, but you can use an alternate payload that weighs less if you want to hand ram the drivers. Otherwise, without the driver rammer tool, you will need to use a hydraulic press to consolidate the fuel enough to get 9 seconds of burn time.

Once the drivers are all rammed and drilled out, they are fused with a bent piece of black match as seen in Figure 2. The end of the match is hot glued to the tube wall so that it can not fall out of the hole. I prefer this method to the alternative of tamping the choke hole full of powder, which will cause a delay before the driver reaches full thrust. The method shown in Figure 2 results in instantaneous ignition of the driver, and takes fire very easily from a second piece of match tied into the final nosing. The match inserted into the choke is intentionally not directly connected to anything else, since the quickmatch fusing ring is subject to pulling forces that would potentially yank it out of the choke hole were it connected directly.

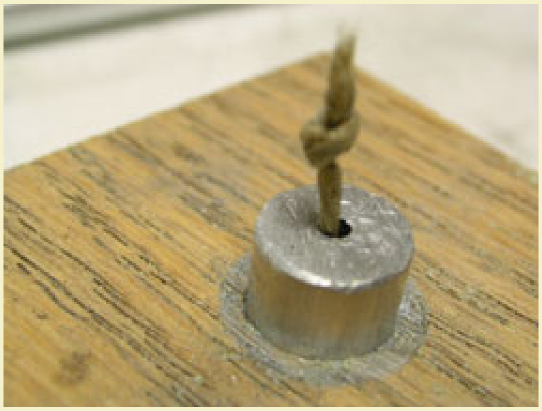


Figure 6: Knotted string passed through the ramming nipple.

The drivers are completed by nosing with two turns of 30 lb kraft as seen in Figure 3. At this point the drivers are ready to be fastened to the frame.

When making the tethered lances, the easiest way to attach the string is to ram it into the clay plug, as seen in Figure 7. This is done by using a special ramming base that has a 1/16" hole drilled all the way through the nipple, shown in Figure 5. A 3 foot strand of thin flax or hemp twine is knotted at one end and passed through the nipple hole so that the knotted end sticks out as seen in Figure 6. The tube is then placed over this and the clay plug is rammed on top of the string, thus locking the knot into the clay so that it can't easily pull out.

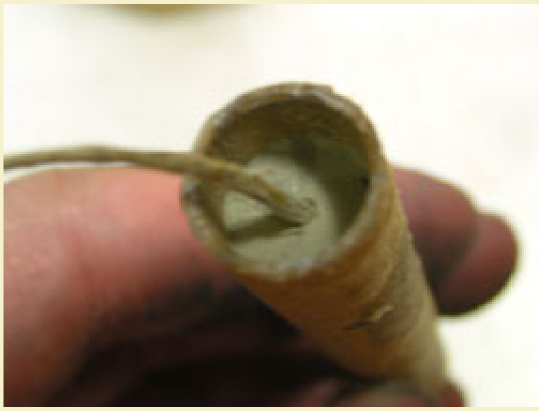


Figure 7: Finished plug with nicely centered twine.

An alternate method to plugging the lance tubes is to ram small wads of glue soaked paper into the ends and letting them fully dry. A small 1/16" hole is then drilled through the paper plugs, then the string is knotted after it is passed up through the bottom of the tubes. This method is a little slower, but removes the need for any special tooling and works equally well.

Because of the rammed plugs in the color lances, the tubes need to be a little thicker walled than usually required for a lance. The tubes shown in Figure 4 are dry rolled from sheets of recycled 60 lb kraft measuring 7" long x 3" wide, with paper grain running in the short direction. The tubes are rolled on a 3/8" diameter former, then plugged as described above. The tubes are then charged with green lance composition to a height that will result in a 15 second burn time. The tubes are then nosed with a 3" x 2-1/2" long strip of 30 lb kraft, into which a stick of black match is tied in with a clove hitch. A batch of finished lances is seen in Figure 8. The black match should only protrude beyond the nosing by about 3/4 inches.

More...

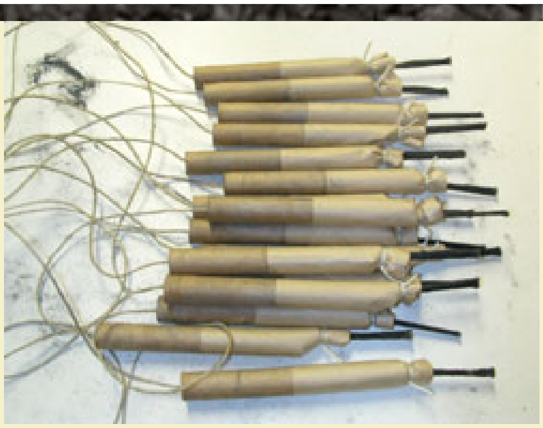


Figure 8: Completed lances ready for stringing onto the frame.

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24" Girandola...

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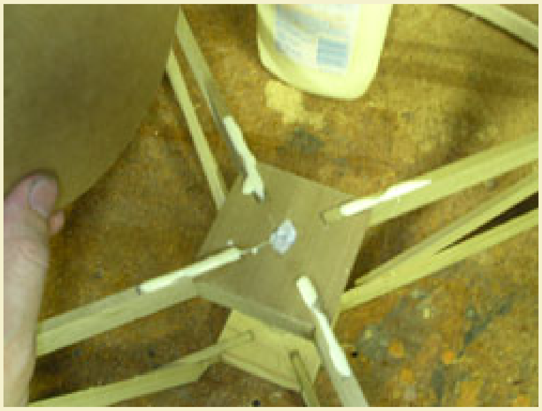


Figure 9: Gluing the shell platform disk on top of the frame.

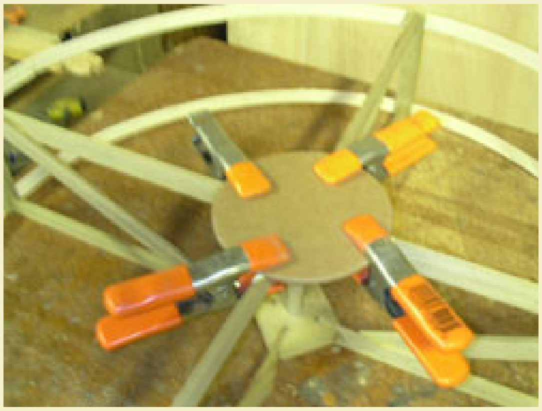


Figure 10: Using spring clamps to make sure disk is firmly planted.

The horizontal drivers can be constructed the same way as the vertical ones, only it is not necessary to ram them with as much force since they will be using a slower burning composition. A mixture of ball milled meal with an additional 25% charcoal added will work well using the same driver dimensions. Extras such as titanium, ferro-titanium, steel filings, fire-fly aluminum or additional coarser charcoal can be added to taste depending on the effect you want. The first set of drivers only needs to burn about six seconds to get the frame moving and allow the lances to drop out and spin up to the same plane with the girandola. The second set is intended to burn all the way up during flight, adding significantly to the width of the rising tail. When using the lance rings, I like to avoid using bright effects such as titanium of flitter on the rising set of drivers, since too much brightness will detract from the ring effect.

The gerbs are made from 5/8" I.D. tubes that are about 3" long. They are rammed with a clay plug at one end and left unchoked at the other end. The Winokur silver gerb formula works well with no choke when suspended upside down, dropping a nice silver glitter effect with good duration and density.

The ball shell can be anything you like of course. The one used here is a paper double petal with Lancaster Yellow glitter to Dixon Gold on the outer stars and my Emerald Green on the inner petal. The construction of this shell is described here.

The charge heights in all these devices must be tested and figured out on an individual basis. I will usually retest each new batch of composition when building a new girandola, since timing is so critical here. You don't want anything left still burning by the time the shell goes off, and you don't want the ring or horizontal drivers burning out half way through the ascent either.

The duration of the vertical drivers are what will determine the time values of everything else, so measure these first and design around it. All the times given here are based on a vertical driver burn time of nine seconds. You must adjust the values accordingly for the burn time of your own drivers. Note that the shell time fuse has an extra second of delay built into it just to give everything time to extinguish, since everything never ignites at the exact same time.

Assembly

Once you have all the components shown in Figure 1 produced, you are more than half way done. It does take several hours to strap all this to a frame and fuse it together though. The frame used here is built as described here.

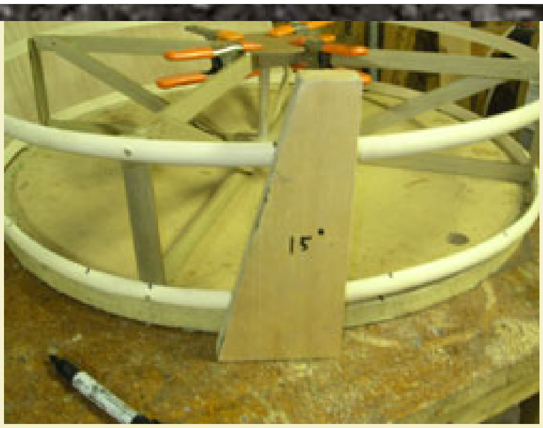


Figure 11: Using a 15 degree angle jig to mark driver connection points.

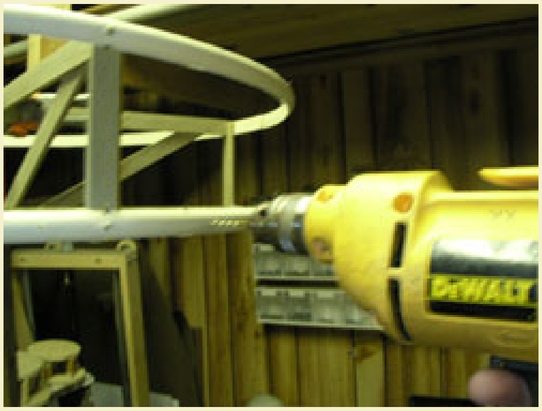


Figure 12: Drilling 3/32" holes through lower ring where tethered lances will be fastened.

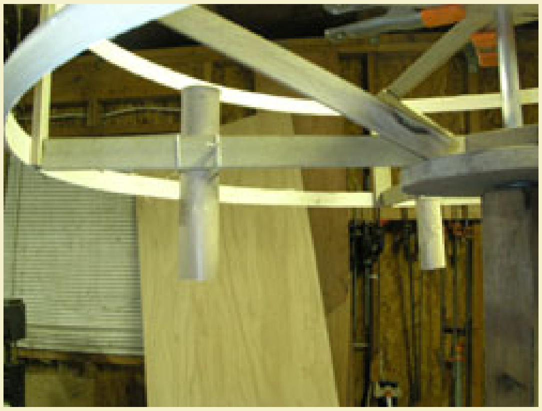


Figure 13: Tying the gerbs onto the lower inside spokes of the frame.

Before you start fastening drivers to the frame, a few modifications need to be made. First you will need to attach a cardboard disk to the top where the header will be attached. Glue is applied to the tops of the frame spokes, then spring clamps are used to hold down the disk as seen in Figure 10. Note in Figure 9 that a wad of paper has been stuffed in the axle hole, which prevents glue from dripping down into the tube and jamming the pin when placed on the launch pad. Note that you won't be able to use long launch pins with this girandola, since the center shell blocks the pin hole. Really you should not be using launch pins that protrude beyond the top of your frame anyway, as long pins just cause your girandola to waste valuable flight time trying to work their way off the pin. Only two or three inches of pin are all that is needed.

It is a good idea to mark your frame where the drivers will be fastened. This way you get even placement of your drivers with a consistent firing angle. If you marked the driver placement on the bottom ring as mentioned earlier then all you need to do is mark the top ring. Figure 11 shows an angle gauge that is aligned with the bottom mark to find where the top mark will be. The drivers are placed 15 degrees from vertical, thus the piece of scrap wood is cut with a 15 degree angle.

Since this girandola will have a lance ring, you will need to drill a series of 3/32" holes around the lower frame ring where the strings will attach. The strings will be passed through these holes and then knotted one or two times to keep them from pulling back out. The holes should be located about an inch to the right of each driver mark, as seen in Figure 12.

The type of twine used to assemble girandolas is pretty important. The twine needs to be coated with a tacky substance such as bees wax or tar. This sticky coating helps the twine grip the driver and frame members so that everything stays tight, and also keeps the knots from slipping into a loose tie point as you work. If you do not have any waxed twine on hand, it is not too difficult to make some yourself. One method is to fix a block of wax in a vice and run each segment of twine through it back and forth several times to coat it. This can be a bit tedious when you have almost 50 pieces of twine to coat though. An alternate method is to melt some bees wax in a hot pot and drag some twine through it onto a rotating frame as when making black match. It is important to use bees wax and not candle wax, however, as the latter is not tacky and your knots will slip (which is what you are trying to avoid by using wax in the first place). A high quality waxed linen twine can also be found at PyroSupplies.com, which is the twine being used in the photos here.

Tar is the traditional coating for girandola string, which works even better than the wax but it is not commercially available anywhere that I have ever heard of so you have to make it. The tarred string is a little messier and trickier to make than the waxed string, so it will have to be the subject of a future article.

Start by cutting 48 segments of waxed or tarred twine that measure 22 inches long. The string dispenser described here can make short work of this task. The dispenser is placed 22 inches from a table edge or other marker, then pull out to the marker and drop the string down on the razor to rapidly cut the segments.

It is easiest to tie the items onto the frame by placing it on a launching stick that sits about eye level. This way you can easily spin the frame as you work, and it is easy to see what you are doing. Trying to work with such a large frame while it sits on a table top would be quite difficult.

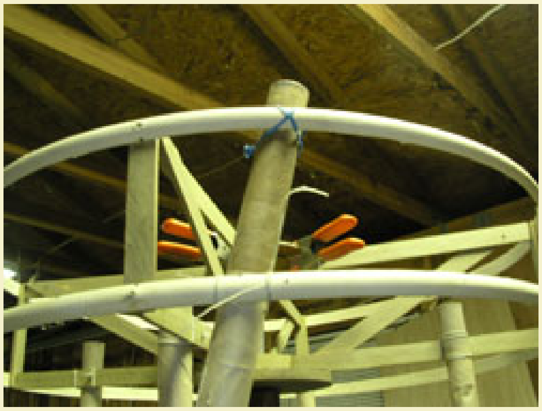
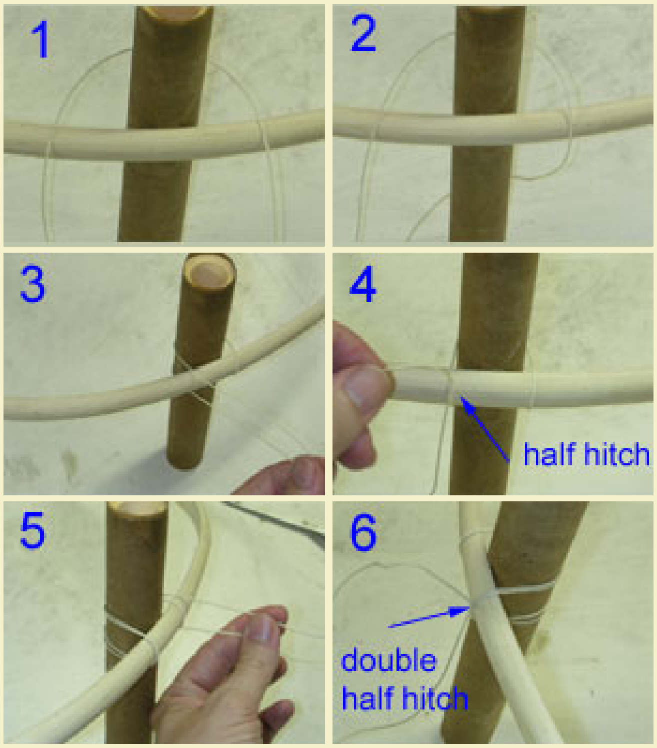


Figure 14: Temporarily holding the top end of a driver using a rubber band while the bottom end is tied.

The first items to be tied to the frame are the gerbs, which are located on the lower spokes as shown in Figure 13. The sequence for tying a tube onto the frame is shown below, which is the same knot used for all drivers except for the horizontal drivers (since they don't cross perpendicular to a frame member).



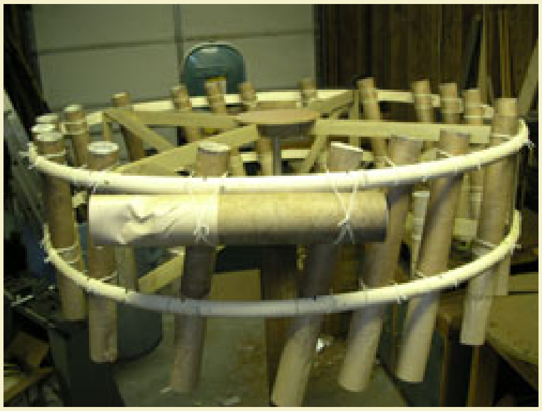


Figure 15: Tying on horizontal drivers after all vertical drivers are attached.

Next attach vertical drivers at the 16 points that were marked on the frame. It helps to temporarily hold the top of the driver to the upper ring using a rubber band while tying the bottom end, as seen in Figure 14. The rubber band is then removed to tie the top end. After the first 16 drivers are attached, add one more driver between two existing drivers in each quadrant of the frame. When expanding the driver count beyond 16, you always have to add them in pairs at opposite sides of the frame in order to keep it balanced. Thus the driver configurations must increase in multiples of two, from 16 to 18 to 20 etc.

The last items to tie on are the horizontal drivers, which are also done in pairs on opposite sides of the frame to keep things balanced. Be sure that the direction of thrust for the horizontal drivers matches the direction of rotation that will be generated from the vertical drivers, as seen in Figure 15. Getting these backwards will result in a girandola that actually slows its horizontal rotation and could even stop rotating altogether during mid flight!

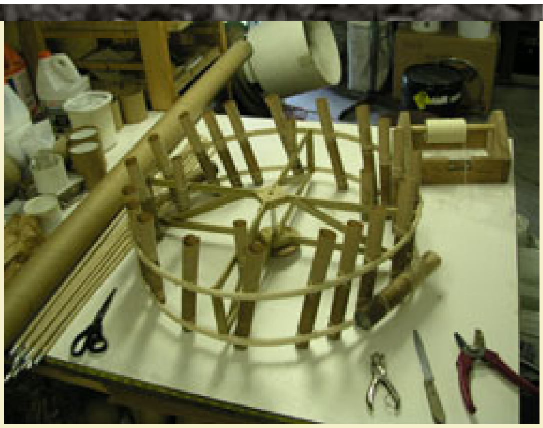


Figure 16: Frame is set upside down for fusing of drivers and gerbs.

Once everything is tied onto the frame, it is removed from the stand and placed upside down on a table for the fusing process, as seen in Figure 16.

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24" Girandola...

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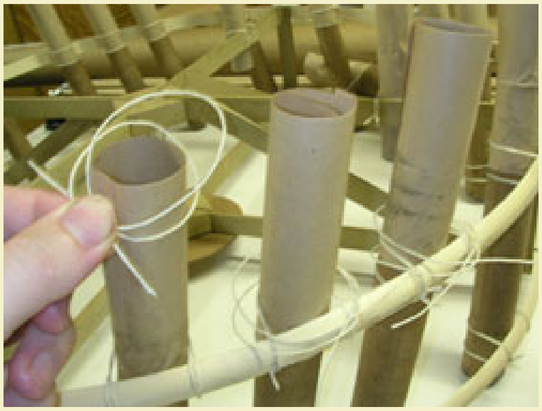


Figure 17: Placing loose clove hitch ties around each driver to be nosed.

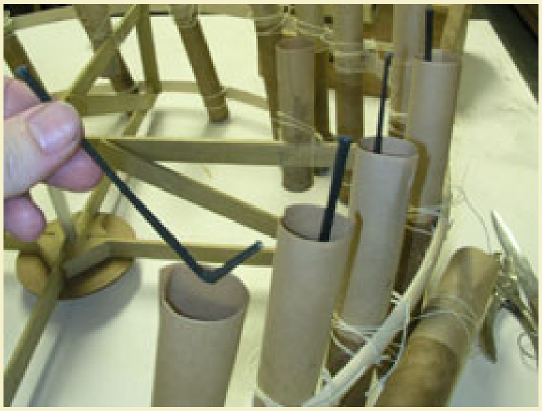


Figure 18: Inserting sticks of black match with a hooked end into each vertical driver.

Fusing

In preparation for tying off all the nosings (28 in this case), I find it saves a lot of time to pre-tie some loose fitting clove hitch knots and slide them over each casing as seen in Figure 17. The clove hitch is first tied around two or three of your fingers, then slipped off and cut free. When you are ready to tie of the nosings, simply slide the pre-tied knot in place and pull the two strings. This way you can tie all the knots one after the other in rapid succession instead of trying to fish string in and around each driver one at a time.

The first items to fuse are the ring of 20 drivers, which are fused with a single hooked stick of high quality black match cut to a length that will give you about an inch of bare match above the nosing paper. The black match is hooked on the end going into the driver, as seen in Figure 18. This helps prevent the sticks from being pulled out from violent lurches that the ignition ring may undergo as the hot gases race through it. This match needs to be a good quality seven or eight strand construction with a solid coating of BP into the core, since it will get bent up a bit while feeding the ends into the ignition ring. Simply insert a stick into each driver and then cinch the nosing paper around it using the pre-tied clove hitch knots.

Once all the vertical drivers are matched, it is time to make the ignition ring that fuses them all together. This is made with several pipes of hand-rolled 3/8" I.D. pipe that has been internally foiled as described here. The foil is to protect the drivers from accidental ignition by sparks from the horizontal drivers or even sparks from other fireworks at the launch site. Failure to heed this step can lead to problems more often than you might think. I've never had things fire out of sequence even once since I started using this type of fire resistant pipe.

Begin by bending an empty stick of pipe around the drivers and marking where the fuse points will be, as seen in Figure 19. Make sure the end of the pipe starts between two drivers when doing this, since it takes multiple pipes to make the full ring and you want the joints to fall between the drivers instead of right over them.

Once the first pipe is marked, use a paper hole puncher to cut half circles where the marks are, as depicted in Figure 20. Then you will need to flatten out the pipe and insert two sticks of good quality black match down its full length. One stick would probably work if you have good match, but two makes for better insurance. Two sticks of match are used for all the piped connections throughout the construction of this device.

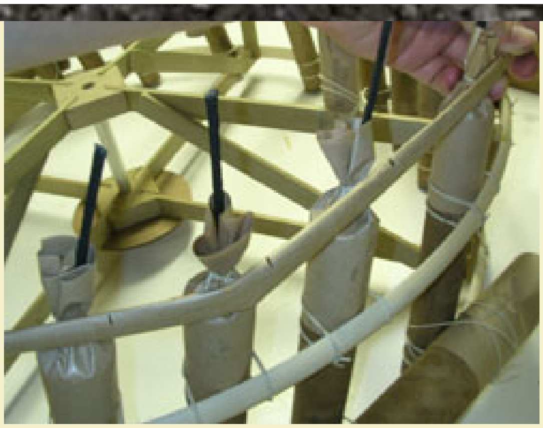


Figure 19: Marking insert points on empty match pipe where drivers will connect.

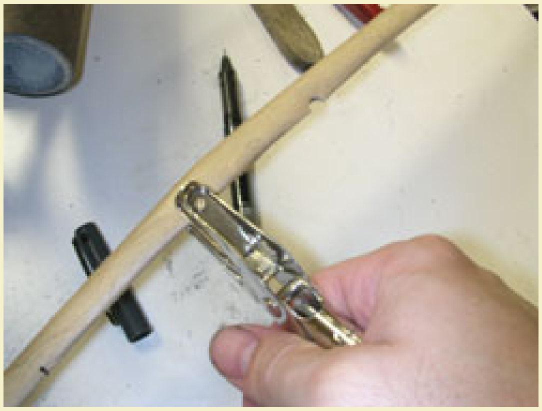


Figure 20: Using a paper hole puncher to open the pipe at the marked connection points.

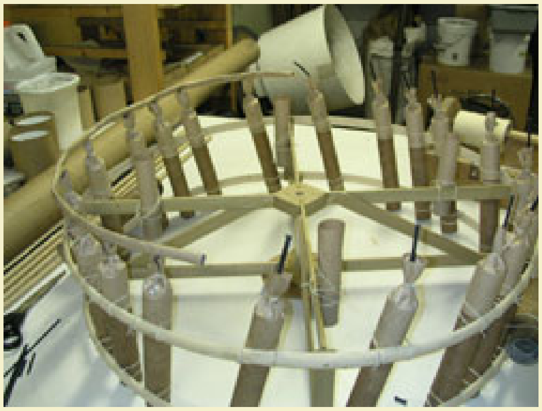


Figure 21: Inserting the driver match into the punched fused pipe.

Once the first segment of pipe is prepared, bend it back into a curve and work it into position by feeding the match stick from each driver into its corresponding hole. You may need to enlarge the hole with the tip of a pencil if the match has a hard time fitting inside. Figure 21 shows the first section of pipe put in place. Note that both ends fall between drivers, thus keeping the joints in a place that won't interfere with anything. When joining the next piece of pipe onto the end of the previous one, you will need to crimp the end of one piece and insert it inside the other. A piece of foil tape can then be used to secure around the joint so that they don't slide apart.

Figure 22 shows the completed ignition ring for the drivers, which takes about two and a half sticks of three foot match pipe to make. The next step is to foil over each fuse junction, as seen in Figure 23. A piece of foil tape is draped over the junction between the driver and the ignition ring, which helps protect any exposed black match from stray sparks that could set the ring off too early. Figure 23 shows the folding pattern for the foil in three stages on three different drivers. The foil tape makes these junctions quite a bit sturdier, such that you can actually rest the completed girandola on it's ignition ring without crushing or crumpling any of these fuse junctions.

It helps to think of your network of quickmatch pipes and junctions as a plumbing system. For a brief second, these pipes will be under pressure with heated gas flowing through them just like water flows through pipes. The gas runs faster than the actual flame front burning on the fuse, and it is the gas that actually ignites everything. The stronger the pipes are, the longer they will be able to contain the pressure without bursting, thus the longer your effects will be exposed to the hot gases they need for ignition. Keeping the pipes free of crimps and blockages also helps increase the speed and efficiency of ignition. Thus you don't want to tie off the nosings around single match strands too overly tight, otherwise you create a fire block. For multiple match strands this is not as much of an issue because there will always be an air gap between the strands for gas to get into. The foiled junctions over the drivers are like T-joints in a plumbing system, and their resistance to fire and pressure help insure that hot gasses are quickly transmitted through tiny gaps around the tie-off points.

With the main ignition ring complete, you can now begin tying the remaining items into it. Each of the four glitter gerbs need to be tied into the ignition ring. This can be done by punching a hole into the side of the ring using an awl, then using a pencil tip to enlarge the hole to the size shown in Figure 24. Here we see a tie-in point for one of the gerbs, showing a short stick of bare match being inserted into the ignition ring. This junction should be foiled over with one or two turns of foil tape to protect any exposed black match from sparks. The opposite end of this connection pipe has a short stick of bare match protruding as well, which is bent into a hook and inserted into one of the gerbs. One opposing set of gerbs can have the nosing tied off, while the other set will need to have an additional pipe running up to the 6" shell so it should be left untied until later.

When making all the adjoining connections into the ignition ring, it is important to pay attention to the direction of rotation the girandola will take. The pipe should run in the direction of the airflow rather than against it, otherwise you create a spark trap between the two pipes where a spark could blast it's way between the pipes where no protective tape exists. Such a spark could find it's way into the bare match at the junction and send the girandola flying ahead of schedule!

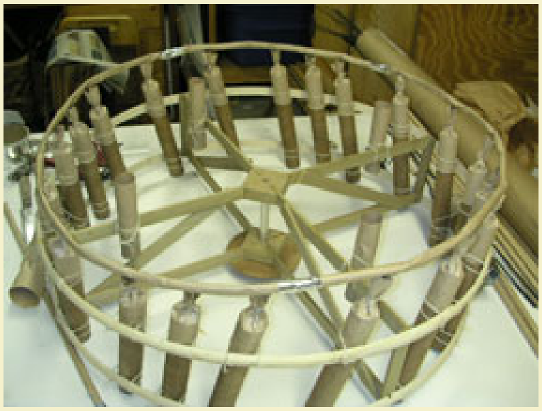
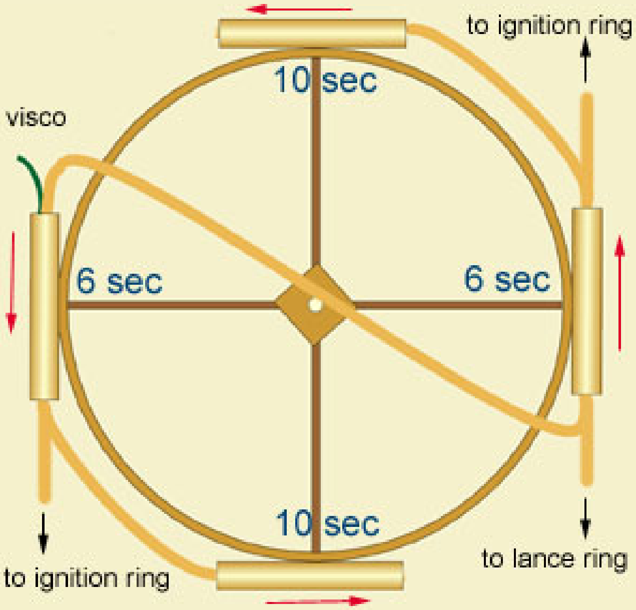


Figure 22: The completed ring takes two three separate pipe segments to complete.



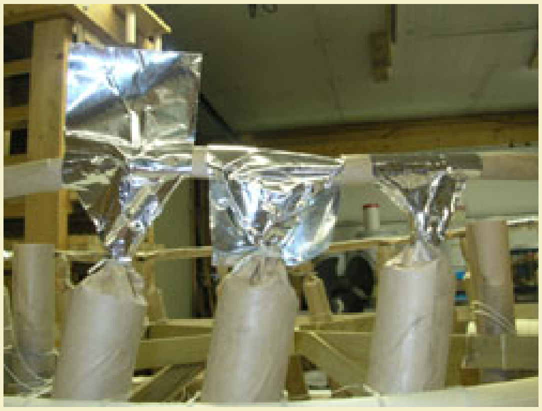


Figure 23: Taping off connection points with foil tape.

The diagram above shows how the horizontal drivers should be fused together. The first pair ignite along with the lance ring. It will take about a second for the lances to burn off their nosing so that they can drop down, after which the drivers will spin them around until they rise up to the same level as the frame they are attached to. After six seconds, the second set of horizontal drivers are ignited from the back end of the first set of drivers. At this time the main ignition ring will also take fire and the girandola will lift off. The second set of horizontal drivers will continue for the full duration of flight, burning out just before the header explodes.

Note that the long piece of quickmatch that runs across the frame should be routed through the center of the frame, not below or above it. This insures that it does not cover the launch pin hole and accidentally get in the way.

More...

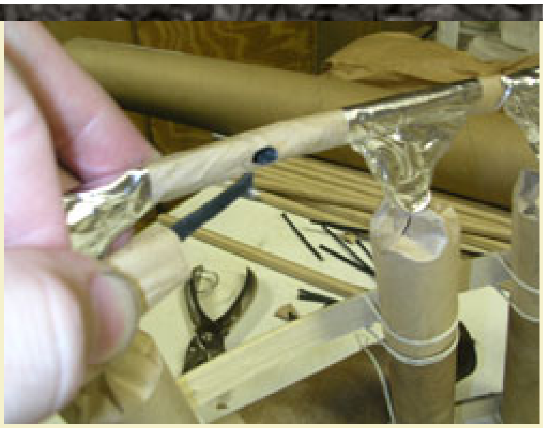


Figure 24: Inserting connections for fusing one of four gerbs.

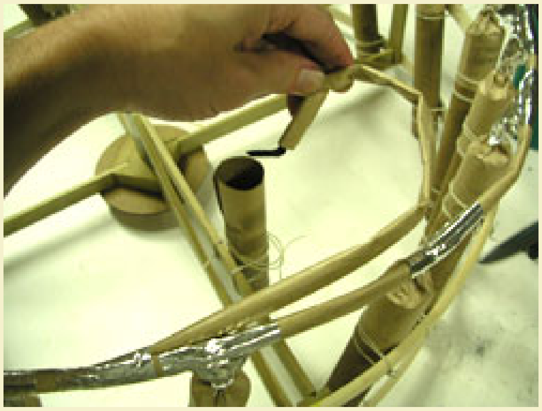


Figure 25: The hooked stick of blackmatch protruding from the quickmatch is inserted into one of the gerbs and tied off.

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24" Girandola...

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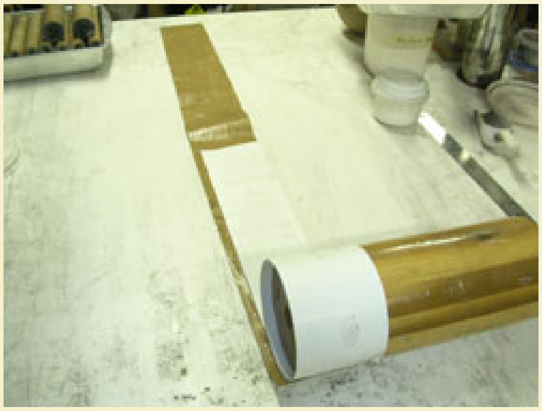

Figure 26: Rolling half of a Maltese style canister to use for a ball shell holding fixture.

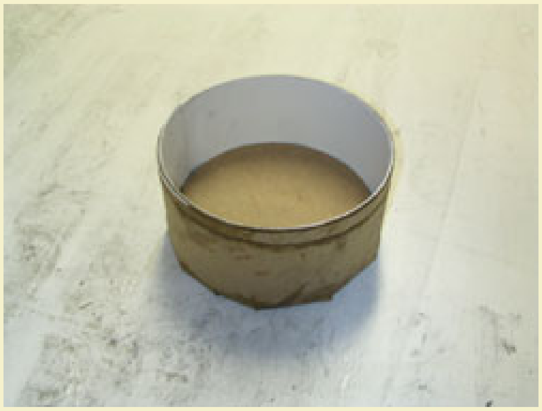

Figure 27: The completed shell mounting fixture.

Attaching the Header

At this point you have a solid girandola capable of lifting up to three pounds of effects to a respectable height. The less weight you add onto it then the higher it will fly of course, but the 3 lb limit will still get it up to the standard height. Adding nothing at all would probably allow it to go to a pretty spectacular height.

To attach the six inch ball shell at the center, you will need to make a cup-like holding fixture, seen in Figure 27. This is rolled on a 5" case former using the Maltese style of canister shell construction. That is, two turns of pasted poster board inside of two turns of recycled kraft, then pleated down over an end disk using a knife to cut 1-1/2" long tabs at the end. The cup walls should be 2" tall after it is completed.

After the cup dries, use a knife to slot some 1/2" tabs all around the edge, then flare them out as seen in Figure 28. This cup is secured to the center platform on top of the frame using hot glue, also seen in Figure 28.

The six inch shell built for the header needs to have a time fuse that burns one second longer than your vertical driver duration, which is 10 seconds in this case. That is quite a long time fuse, measuring 4" between cross match holes when using standard Chinese time fuse that burns about 2.5 seconds per inch. There will be at least 2 inches of time fuse sticking out from the shell.

The shell is hot glued into the holding cup with the time fuse pointing upwards, as seen in Figure 29. The tabs are bent slightly outward prior to applying the hot glue so that it will conform to the curved shell wall. If you were using a canister shell, you could omit the holding cup and just glue the shell directly to the center disk on the frame.

The header shell is pretty safe from centrifugal forces as long as it is mounted dead center on the frame. Anyone who remembers standing dead center on a rapidly moving merry-go-round as a kid knows that there isn't much force at that location. But get even a little off center and you find yourself on the verge of becoming a playground statistic! To help insure your shell doesn't suffer the same fate, twine is used to secure it further. The twine runs through holes drilled through the frame spokes near the ends, then loops back and ties off on the time fuse. While one long piece could be used to tie off all four supports, it is easier to use two separate pieces to tie two sets of two. Start by securing one end to the time fuse using a clove hitch, then loop through one frame member back up to the time fuse again. Pull the twine tight and wrap it around the time fuse a few more times to keep the tension, then loop to the opposite side of the frame. The twine is brought back to the time fuse again, looped around a few times and then tied off with a final clove hitch. The other set of supports are tied in the same way.

The time fuse is then cross matched and fitted with a bucket tied on above the support twine. This bucket will receive two passfire pipes that tie into one of the gerbs. The dual fusing is for symmetry and redundancy. It is a good idea to foil over the top of the bucket after the two passfire pipes are tied in, otherwise it becomes a spark trap. I prefer to foil the side of the bucket as well, since it is a thin walled paper tube that can be easily penetrated by fast moving sparks.

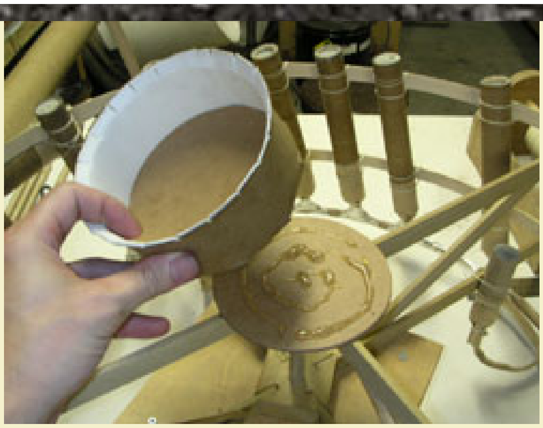

Figure 28: The rim of the shell fixture is slotted and flared out prior to attaching with hot glue.

Installing the Lance Ring

The lance ring is the last effect to be attached, since the strings would get in the way when installing the other components. It highly recommended to work with the girandola on the launch stand for this step, since this allows the strings to hang down out of the way. The string from each of the 16 lances is passed through the holes drilled in the lower ring, then double knotted at the end so that it can't pull back through. If the holes are too big to reliably keep the knots from pulling through, you can just tie the strings off around the frame.

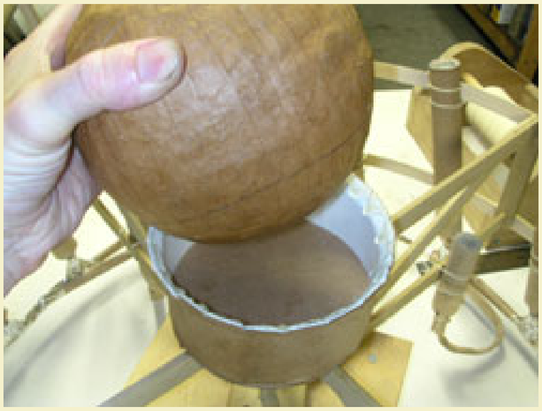

Figure 29: Hot glue is used to secure the 6" ball shell into the holding fixture.

Once all the lances are dangling down from the frame, you are ready to install another ignition ring that will pass fire to them all at once. This is a band of double matched pipe that wraps around the lower ring, into which each of the lances will be inserted.

Making the ignition ring for the lances is pretty similar to the ring made for the drivers. An empty segment of match pipe is bent around the frame and marked at intervals where the lances will be inserted. The pipe is then removed and a paper hole puncher is again used to perforate the pipe. Two sticks of black match are inserted into the pipe and it is finally tied off to the frame using a series of clove hitch knots spaced at intervals as needed. Figure 32 shows the fluted pipe after it has been tied to the frame. It is difficult to see the string from the hanging lances in this picture, but if you look real closely you can see that they are there.

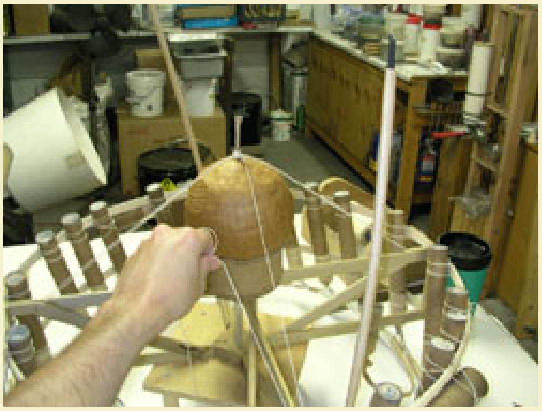

Figure 30: Twine running through the frame members is wrapped around the shell's time fuse for extra reinforcement.

Attaching the lances is a simple matter of sticking the bare match from the lance into the punched holes, as seen in Figure33. This will orient the lance sideways on the frame, with the string making a loop from the frame to the end of the lance. Note that the lance should be inserted so that the ignition point will be facing the direction of travel as the frame rotates. Spark traps aren't as much of an issue in this case since the lances are among the first things to ignite, but it is just good practice to always eliminate spark traps on rotating wheels where crevices exposed to down-wind sparks can expose bare match to unwanted ignitions.

A piece of foil tape is placed over the connection point of each lance in order to prevent accidental ignition from other sparks that may be present at the shoot site. The lance is then secured to the frame with a clove hitch that wraps around the nosing paper. The lances must not be secured by tying anything around the lance tube itself, since they need to be free to drop down once the nosing paper burns away.

Figure 34 shows how the lanes pack together behind one another. While it is possible to fit more than 16 lances on the frame, entanglements become more likely as the number increases. When two adjacent lances become wrapped around each other after dropping down, they tend to burn as one point of light instead of two, and will be located closer to the frame than the other lances. This detracts from the ring effect by causing a deformity in the symmetry.

Entanglements are less likely if the frame is spinning fairly fast before the lances break loose, as they will tend to fly outward instead of dropping downward. A delayed ignition of the lances can be achieved intentionally by adding a segment of time fuse into the leader that ignites the lance ring. You just have to remember to decrease the burn time of your lances by an equivalent amount if using this delay method.

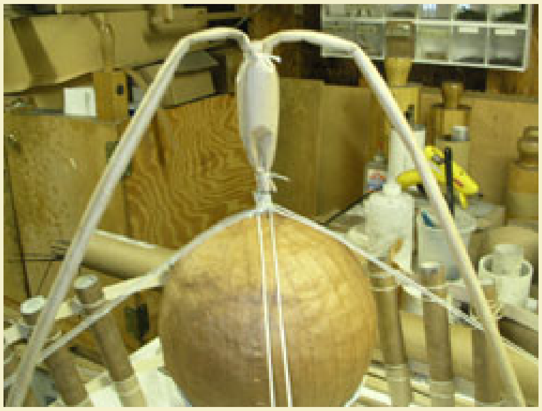

Figure 31: A bucket is tied to the shell's time fuse and matched with dual leaders connected to the main ignition train.

Launch Notes

This size girandola can weigh between seven and twelve pounds, depending on how densely the drivers are loaded and how much payload you put on it. Due to this heavy weight, it is a good idea to fit your launch stick with a support platform as described here. The launch pin should not have a sloppy fit into the girandolas axle, but it should not bind when lifted on or off either. The pin only needs to stick up above the support platform by about two inches, so disregard any myths you may have heard about overly long launch pin requirements for girandolas.

When staking out your launch stick, be sure that there are no support braces or support wires located closer than four feet from the bottom of the girandola, otherwise the lances could become entangled on these supports when they drop down.

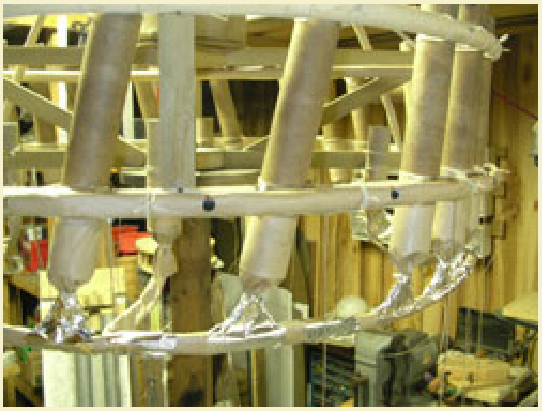

Figure 32: A ring of matched pipe is tied to the lower ring. Note the holes pre-punched where the lance fuses will connect.

Care must be taken when transporting the girandola to and from the launch stick or in and out of transport crates, since the strings can easily get hung up on things and yank out a lance. It is best to drape the string loops up over the top of the drivers until the girandola is ready to fly. Then prior to launch, make sure each of the strings for the hangs down in a clean loop that does not criss-cross the other strings or get hung up on the frame somewhere.

With 45 ignition points, 6 separate timing groups and over 30 feet of fusing, it always amazes me that these things manage to work at all, not to mention perform as designed. But even when things don't go as expected, something entertaining almost always happens when you set fire to this much pyro strapped to a single frame!

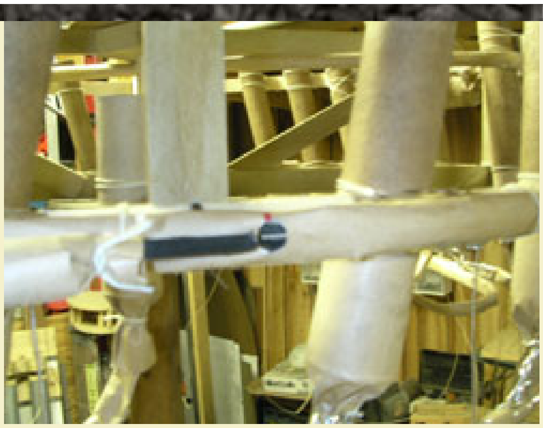

Figure 33: Inserting one of the 16 lances into the ignition ring. Note the dual strands of black match inside the pipe.

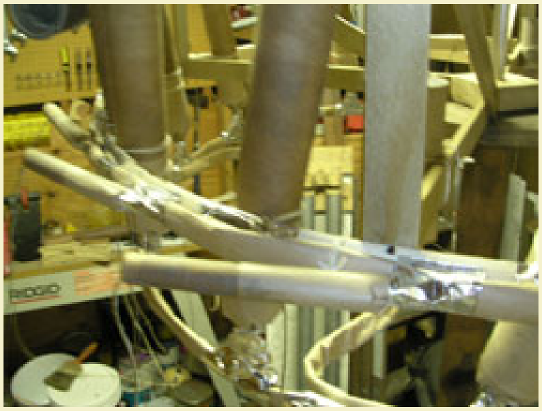

Figure 34: Side mounted lances are tied off and foiled over to protect the connection points.

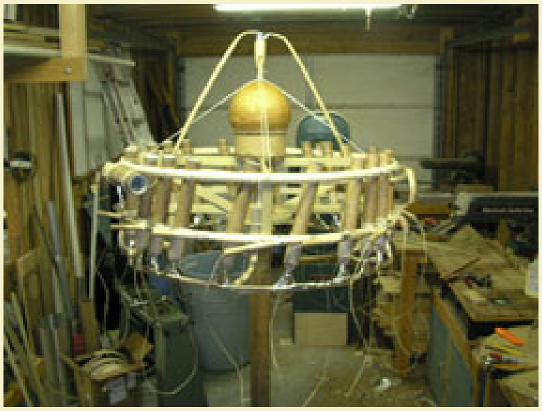

Figure 35: The finished girandola showing the dangling lance strings the way they should look prior to launch.

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Beginner Project... **Page 1**

Mini Girandola

by ***Jim Biersach***

Figure 1: Plastic ice cream bucket or similar sized container.

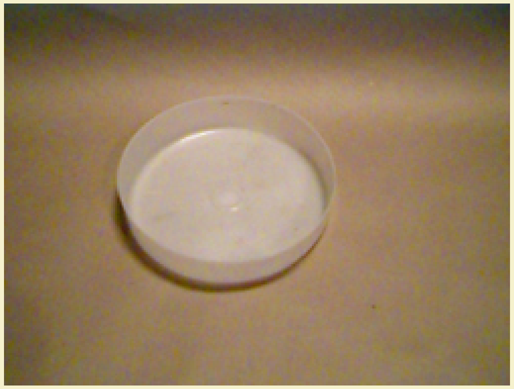

Figure 2: Bottom removed from bucket.

Materials:

- one gallon ice cream bucket
- zip ties or wire
- 6 to 8 class C rocket motors
- quick match
- short piece of visco or black match
- 1/4" to 3/8" diameter dowel rod
- 2x2 wooden stake, at least three feet long

Introduction:

The first girandola I ever saw was at the PGI convention in Pennsylvania. It was paraded around and looked like a big birthday cake. They hauled it out to the edge of the shoot site with a lot of hoopla and fanfare. When they lit it up it was very impressive, but I had no idea what it was or how it worked.

Later on while at the 1997 PGI convention in Amana, I found the girandola had become a competition event and there were three or four entries. My favorite entry was one made by Tom Dimock, later to become famous for his girandolas, which went up and hovered for a few seconds, then took off into the sky (winning second place). At this point I became even more interested in these flying contraptions.

At a later PGI convention held in Wyoming, Tom Dimock started giving seminars on how to make these newly rediscovered devices. It was at this point that I became hooked. Tom explained the traditional method of building bamboo frames, then mentioned that people had also made simple frames from the bottom of five gallon buckets.

Bill Kimbrough, another famous girandola builder who is largely credited for bringing these devices to the American pyro community, gave me some bamboo to make my own girandola and I went home with a big grin on my face. I made a girandola with the bamboo frame and entered it into competition at Fargo the following year… and got third place! OK, there were only three entries, but I was excited none the less.

One night I was thinking about girandolas and the bucket bottom idea, then went to the plastic recycling bin to see what I could find. An empty one gallon ice cream pail looked like it would work well, so I headed down to my dungeon to give it a try. Forty five minutes later I emerged with my first "Mini Girandola," made from commonly available household items.

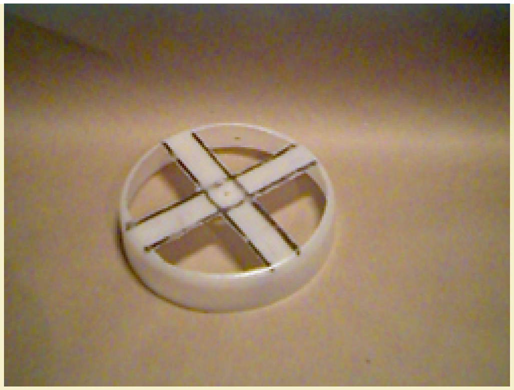

Figure 3: Pieces cut away to create spokes.

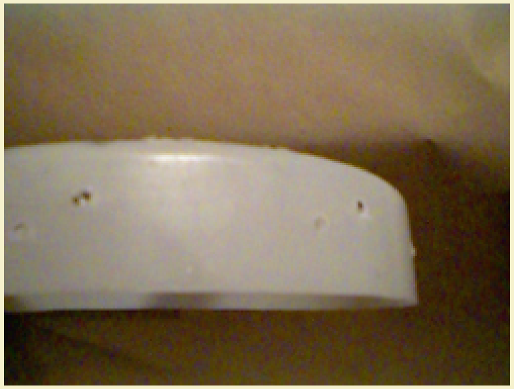

Figure 4: Holes drilled in sides to receive zip ties or wires.

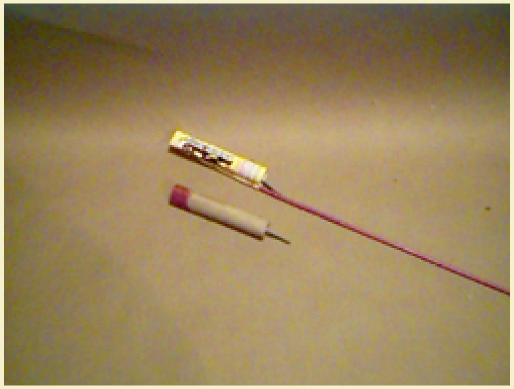

Figure 5: 1/2" I.D. class C rocket used for drivers.

The project shown here uses some class C rocket motors so simplify the project even further so that even very novice pyros can give it a try.

Construction:
1) The first step is to empty a one gallon bucket of ice cream. I hope this step is self explanatory.

2) Now cut the bottom of the bucket off so that it is about an inch and a half tall, as seen in Figure 2.

3) Cut some spokes out of the bottom by removing three or four symmetrically spaced triangular pieces. This lightens the frame and also reduces air resistance as the girandola rises.

4) Drill about a 3/8" hole in the direct center of the bucket, which will be used to mount the girandola on a launching stick.

5) Drill some holes through the side of the frame, which will be used to tie the rocket engines to the frame. Six to eight engines works best here. I have tried twelve, but this did not work as good as expected.

6) Take some class C stick rockets of your choice and remove the sticks. I dip the wick in some prime so that it ignites easier, since class C rockets usually use visco instead of black match for the fuse.

7) Attach the motors to the frame using zip ties or wire. Some people like to hot glue the motor to the frame first before tying it on, which helps hold it in place. The motors should be at a slight angle as seen in Figure 6. This angle is important, as it ensures that the wheel will spin as it takes off. The spinning stabilizes the wheel so that it doesn't flip over when it leaves the launch stick and is a critical requirement for girandolas to work properly.

8) Use quickmatch to connect all of the rocket fuses together in one continuous loop, as seen in Figure 7. Some beginners may have a hard time obtaining quickmatch and will have to make their own by using the techniques described here on Passfire. Holes are punched in the side of the quickmatch wrapper so that the rocket fuses can be inserted into the match pipe. The two ends of the quickmatch should be connected together so that you have one continuous loop for the fire to travel through.

9) Punch a hole in the side of the quickmatch ring and insert a piece of fuse that will be used to ignite the girandola.

10) At this point the girandola is ready to launch. The final step is to make a launch pad that allows the girandola to spin without falling over during the lift off. This is done by mounting a dowel rod vertically into the end of a wooden stick, as seen in Figure 9. The dowel rod should be slightly smaller than the hole drilled in the bucket bottom so that it can easily spin. The length of the pin needs to be about six inches long so that the girandola has time to get spinning up to speed before leaving the pin. You will usually also need some kind of bearing between the launch stick and the bucket bottom, such as a few washers, so that there is not too much friction when the wheel is trying to spin.

Lastly it's time to light er up and see how well you did. If it flips over, then you might need more angle on the engines or a longer pin. If it didn't get off the pin, you'll need to find some larger rocket engines or maybe use more of them. If all went well, then congratulations!

Editors Note:
Almost any kind of plastic container can be used to make small girandolas as long as the plastic is not too flimsy. Tuna cans have also been used with success to make very tiny girandolas that work quite well. Note that as girandolas shrink below about 6" diameter they start to look more like tourbillions, and it is less work to just build a tourbillion to get the same visual effect.

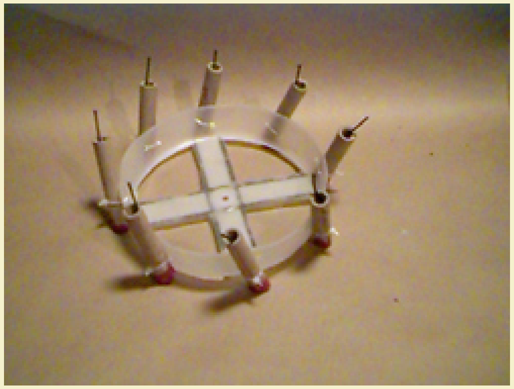

Figure 6: Wheel with motors attached at slight angle.

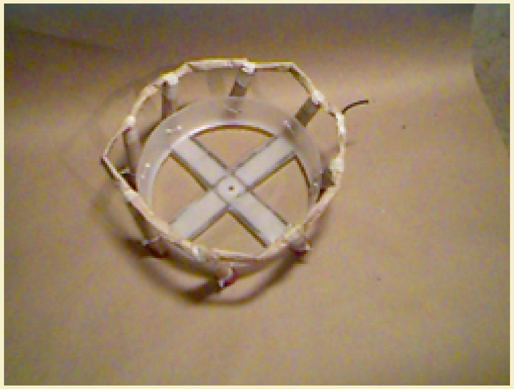

Figure 7: Motors fused together with continuous loop of quickmatch.

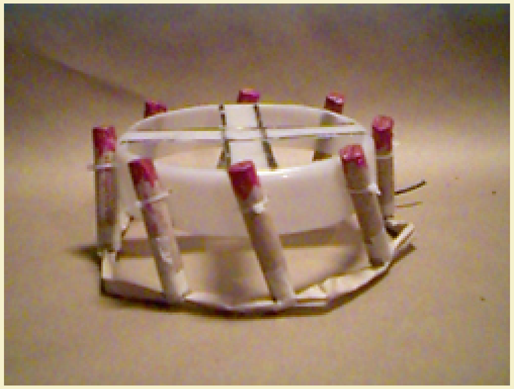

Figure 8: Completed girandola.

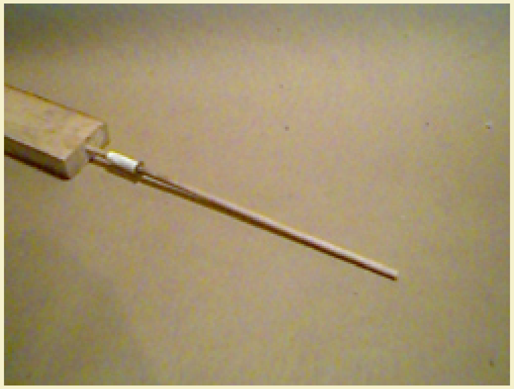

Figure 9: Launch stick with guide pin inserted.

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Design Notes...

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Girandola Design Considerations

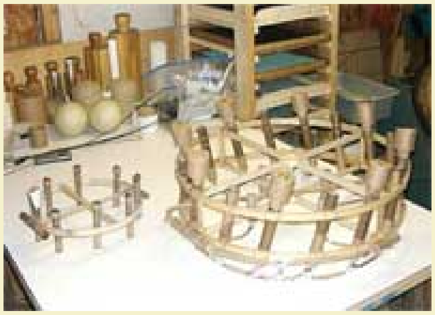

Figure 1: A 12" and 24" girandola.

Introduction:

Girandolas are perhaps one of the most complex types of fireworks commonly made by the hobbyist. These spin stabilized flying set pieces involve almost all aspects of other firework devices! They combine the functionality of rockets, wheels, gerbs, lances, shells and anything else that the designer can lift into the air with them.

The amount of lift a girandola is capable of is much higher than what a typical rocket can provide, which allows this device to carry a much larger payload of effects. The ability to lift such large payloads in a slow and controlled manner is what makes girandolas such an open ended platform for creativity.

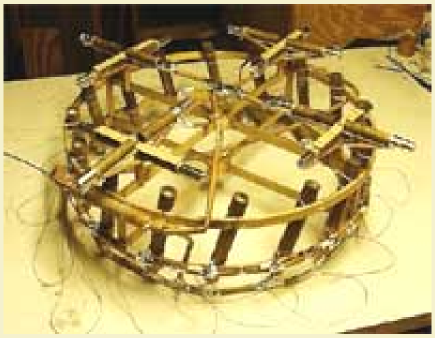

Figure 2: A 24" girandola that launches four quad tourbillions during flight.

Designing the proper amount of lift, arranging the components in a stable fashion and fusing it all together in a reliable manner is what makes girandolas such a challenge. This article touches on the basics behind designing reliable girandolas and some of the different effects possible.

Thrust Calculations:

One of the first things you will need to determine when designing a girandola is the number of drivers required. Many people simply figure this out by trial and error, or even worse, just take an educated guess and send their piece into competition with no testing at all!

While the trial and error method will work, it is very time consuming to build a complete girandola several times just to find out the optimal number of drivers. It is indeed possible to calculate the exact number of drivers you need in order to get your girandola to fly to a desired height.

Stick Test Method:

The most common method of testing girandola drivers is the stick test. For this test to work, you have to know the weight of all girandola components minus the weight of the drivers. This includes the weight of the frame, the headers, horizontal drivers etc. Once this weight is known, it is divided by the number of drivers you think will be required. A wooden rocket stick is then fabricated that equals this weight, and one driver is produced and fired as a rocket using the weighted stick.

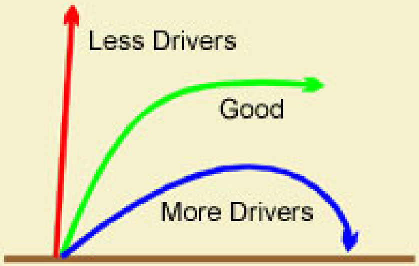

Figure 3: Stick test flight path indicators.

The speed and height of the weighted rocket will give you a good indicator as to how the resulting girandola will perform. If the stick rises too slowly and the rocket arcs back to the ground, then more drivers will be required. If the stick rockets up in a straight line like a normal rocket, then less drivers will be required than you had anticipated. The ideal flight should be a rather slow moving rocket that still arcs quite a bit but never heads back down to the ground (see Figure 3).

While this method still requires trial and error, you only have to build a single driver each time instead of fabricating an entire girandola. Only a single girandola is built for the final test, and if the stick test was carried out correctly then the fully completed girandola should work as anticipated.

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Volume 2, Issue 7

Girandola Design Considerations...

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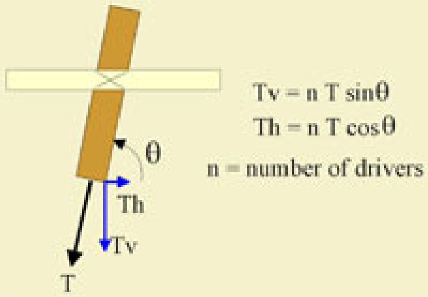

Angled Driver Thrust Calculator:

Driver Thrust = ☐ g

Angle = ☐ deg

Driver Count = ☐

Vertical Thrust = ? g

Horizontal Thrust = ? g

Calculate

Thrust to Weight Ratio Method:

One flaw with the stick test method is that it is not accurate for girandola designs in which the lift drivers will be mounted at an angle, which is quite common for maintaining horizontal rotation during flight. When mounted at an angle, the drivers total thrust will be divided into a horizontal and vertical thrust vector, as illustrated in the calculator to the left. Thus, the usable vertical thrust will be less than the thrust of the driver itself.

In this case it becomes necessary to measure the actual thrust of the driver. While many contraptions have been devised for measuring driver thrust, one crude yet workable method is to build a fixture that allows you to measure the thrust using a digital scale. A piece of plywood that overhangs the edges of the scale to protect it from fallout is fitted with a hole equal to the O.D. of your driver. The driver is tightly inserted into this hole with the nozzle end pointed upward, and the board is placed on the scale. It is recommended that you use an inexpensive scale for this purpose in the event your driver detonates.

A method must be devised for reading the scale when the driver is fired. This can be done with binoculars from a distance, or possibly using a video camera on a tripod. If your readout is large enough, you may even be able to wear a face shield and read it visually from a distance. Make the assumption that the driver will detonate, then devise a remote viewing plan based around that hazard.

There will be an initial impulse from the driver when it first takes fire that is greater than its sustained thrust. Since the weight of the driver is also decreasing as it burns, the thrust readout will appear to decrease as it burns. However, the decrease in weight is not likely to exceed 8% of the thrust value so it can be ignored. You are just trying to get a rough estimate of the average thrust, so you need to pay attention to the range of numbers that will appear on the scale.

Once you have a good thrust reading, it becomes quite easy to determine the number of drivers you need without any further testing. While the thrust values can be used with elementary physics equations based on Newton's laws of motion, I have found that a much simpler method is to maintain a desired thrust to weight ratio for your girandola. Through experimentation, I have found that if the total thrust for a given design is about two and a half times greater than the total weight for the completed girandola, then you will get a very pleasing rate of ascension that reaches a height of around 250 feet if the burn time is at least seven seconds.

If your drivers burn for a longer period, say 10 seconds, then you will want to lower the thrust to weight ratio to around 2.0, unless a very high flying girandola is what you desire. Keep in mind that girandola headers are typically not much larger than 2" shells at the most, so sending a girandola up 500 feet will diminish the perceived size of the header bursts for your audience.

One nice advantage to using the thrust to weight ratio method of design is that you can modify your girandola and still be able to accurately determine the correct number of additional drivers you may need. If you decide you want bigger headers half way into your project, you can just determine the total weight with the new headers and then solve for: thrust = 2.5 x weight. Keep in mind that lower thrust to weight ratios will result in slower ascension speeds, and higher ratios result in higher ascension speeds. Thus, your thrust to weight ratio needs to be dialed into your driver burn time and your personal preference for rate of ascension and final height achieved. The 2.5 value gives you a good place to start with your own designs.

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Vertical Driver Angle:

Although it isn't necessary to angle your vertical drivers, doing so helps maintain the horizontal spin that serves to stabilize the girandola during flight. Some designs utilize horizontal drivers that burn during the entire flight of the girandola, which eliminates the need to angle the vertical drivers. This allows the full thrust of the vertical drivers to be utilized for lift.

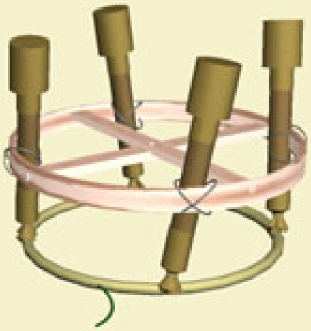

Figure 4: Design with no horizontal drivers (not recommended).

Other designs utilize a rather large angle on the vertical drivers as a replacement for the horizontal drivers completely, as seen in Figure 4. While this type of design can be made to work, it is more prone to failure when all the drivers do not ignite at the exact same time. Since there is no gyroscopic stabilization set in motion at the time of lift off, uneven ignition of the vertical drivers can easily cause the girandola to flip over and become a disappointing display of ground fountains.

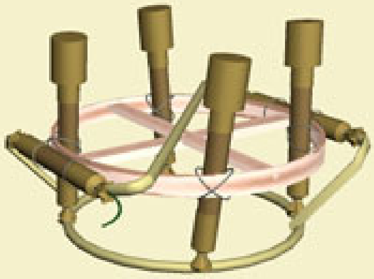

Figure 5: Classic girandola design.

The most common design uses horizontal drivers that spin the wheel up to speed and then ignite the vertical drivers at the end of their burn. The vertical drivers will have a slight angle to them to keep the spin going as it rises into the air. This angle really doesn't need to be much more than 15 degrees from the vertical plane (note that this translates to 75 degrees when using the calculator on page 2).

Driver Design:

Most girandola drivers are end burning black powder rockets, which is to say they have no cavity inside the powder charge. This is necessary in order to maximize the burn time from the driver. Girandolas are not devices meant to rapidly fire into the air in the way that rockets do. The characteristic that sets them apart from any other kind of effect is the long duration and slow speed of their ascent.

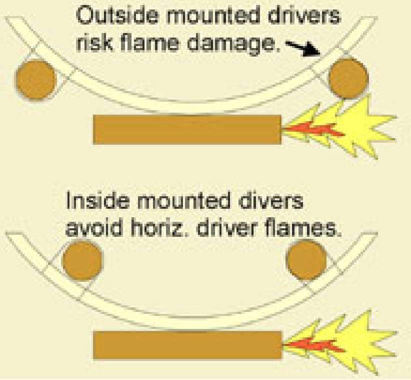

Figure 6: Advantage of placing vertical drivers inside the frame.

All drivers have a design tradeoff between thrust and duration. All other variables remaining constant, higher thrust from faster burning composition results in shorter burn times. While it may be tempting to save work by using fewer drivers that produce more thrust, this approach significantly increases the risks of driver failure during operation. Building drivers that operate right on the edge of detonation in order to reduce the number of drivers required will result in ruptured casings and blown out end plugs at the worst possible times (i.e.- during competition).

It is always a better idea to produce a lower thrust driver that performs well within the tolerance of the tubes and plugs you are using and just use more of them to get the lift you want. It is less stress to make a few extra drivers than to have your girandola blow drivers and fail to get off the pad due to uncontrollable variances in your process, materials, relative humidity or whatever keeps the same thing from working the same way twice.

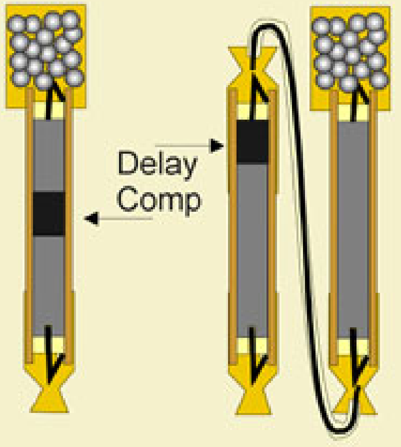

Figure 7: Two methods of producing "bouncing" girandolas.

Figure 7 shows two methods of producing a "bouncing" girandola, which is an effect where the girandola pauses mid flight, sometimes even dropping back towards the ground before a second stage boosts the girandola upwards again. The simplest method is to utilize a delay composition at the center of all the drivers, which is a slower burning comp with less thrust. The normal driver comp is then rammed on top of the delay so that the girandola will resume normal thrust levels after the delay has executed.

A more complex bouncing girandola scheme uses two separate sets of drivers. While this method produces a longer lasting performance, the extra weight that the first set of drivers are required to lift can make this design difficult to implement. This method will require considerably more drivers to achieve virtually the same visual effect.

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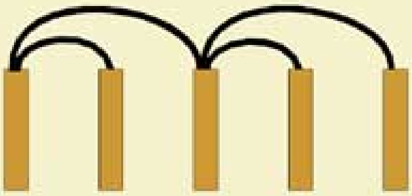

Figure 8: Skip fusing method.

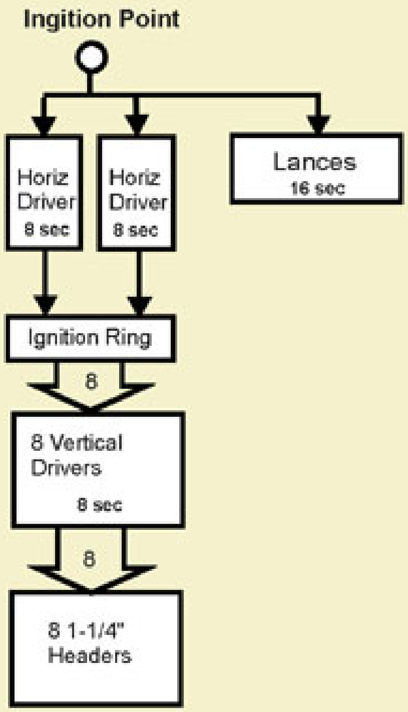

Figure 9: Ignition diagram of an angled driver girandola with lance work.

Fusing It All Together:
Large girandolas containing many effects can contain upwards of 40 ignition points or even more. Reliable fire transfer to each of these junctions is critical to proper performance. This is especially true in the case of the vertical drivers, since they must all ignite at the same time.

One problem that often occurs with the use of quickmatch on complex set pieces is when pieces of match recoil from the rapid movement of gas through the pipes during fire transmission. If the black match that passes fire into the driver choke is physically connected to the piped match leading to it, the match stick can easily be yanked from the choke hole and result in ignition failure. For this reason, it is best not to couple the passfire that enters the driver with the match that ties into the nosing. Fusing the choke with a small piece of match that is fastened to the case with either hot glue or prime slurry is a good way to avoid this problem (see this page for an illustration of this method).

There are a few different methods for fusing all the drivers together in order to obtain rapid fire transfer to all of them at once. One trick used by the Maltese involves a pattern of matching the drivers which is illustrated in Figure 8. The idea is to create multiple channels for the fire to travel so that the fire does not progress in a single-file fashion. The match simultaneously ignites the next driver and also the one after it at nearly the same time. This skipping pattern cuts the propagation time in half.

A second method of fusing the drivers involves creating one large hoop of match I call the "ignition ring." This is a continuous piece of match with no obstructions that allows the fire to shoot around in a ring. Regardless of where the fire first enters the ring, flame propagation heads down the ring in both directions very rapidly. Holes are punched in the sides of the ring to accept pieces of black match from the drivers and anything else it is to ignite.

Anytime a piece of piped match is tied into the nosing of a junction of any kind, bending the piece of exposed black match into a hook is a precautionary step that helps insure that the black match will not accidentally get pulled out of the junction during assembly or even from the recoil during ignition.

When designing the sequence of events that is to take place on your girandola, or any other set piece for that matter, it helps to make a flow chart as shown in Figures 9 and 10. These charts lay out the ignition paths as well as define the timing of events.

The example chart in Figure 9 shows a girandola in which two horizontal drivers ignite first along with a pattern of lance work. Note the redundant ignition path coming from the horizontal drivers to the ignition ring. Should

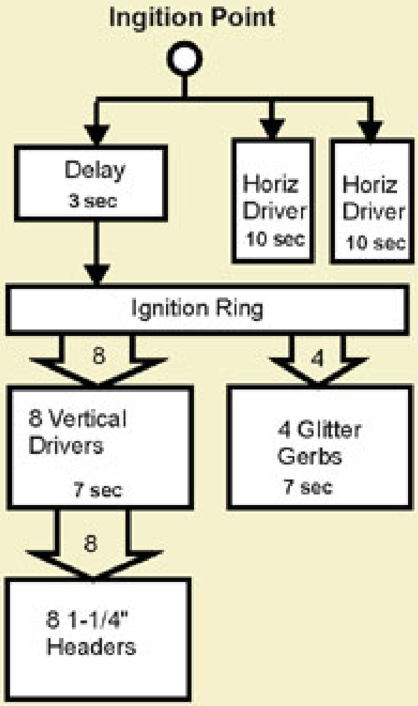

Figure 10: Ignition diagram of a girandola with continuous horizontal drivers.

either path fail, there is a backup to ensure that the ignition ring takes fire.

The example in Figure 10 shows the design for a girandola where the horizontal drivers continue to burn for the entire flight of the girandola. The design could be improved by adding a second delay circuit leading to the ignition ring, once again adding the desired redundancy for insuring ignition of the main event.

Not only do these type of diagrams serve as a good visual aid when designing your girandolas, they make useful blueprints when you reference your notes at a later date in hopes of repeating your efforts. Too many people produce one hit wonders that can not be duplicated months later when they realize they took poor notes on the project.

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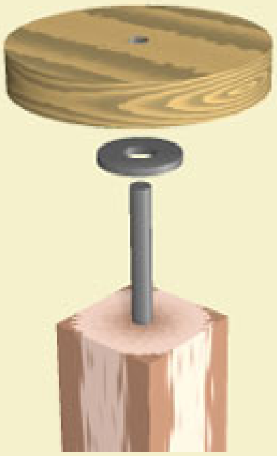

Figure 11: A launch stick with stabalizing platform.

Launch Sticks:
The best girandola in the world will get nowhere without a well designed launch stick. Neglecting this seemingly trivial component can lead to disappointment. Perhaps the biggest mistake I've seen with launch sticks is overly long center pins. The pin that allows the girandola to spin before taking off should be made as short as possible. As soon as the girandola has enough lift to fly, you want it to clear the pin as fast as possible so that it doesn't have to fight friction and lose valuable air time. However, you don't want the pin to be so short that the girandola could flip off the stand in the event of uneven driver ignition. I prefer to use a 1" pin for single frame girandolas and 2" for double frame types.

For small girandolas that only contain a single flat frame, some builders will fasten a cardboard tube into the center hole that slides over the pin on a launch stick. This adds unnecessary weight and can be eliminated by using a different launch stick design as shown in Figure 11. A wooden disk of about 3 inches in diameter is used as a stabilizing platform for the wheel to rest on during launch. This platform must freely spin so that it will spin with the girandola if it needs to. The little bit of time spent making this extra component of the launching stick is well worth the work saved of not having to attach tubes to the center of every girandola wheel you make. This stabalizer disk also helps to eliminate wobble in larger double frame girandolas as well.

Lastly, the stick itself should be firmly grounded. If it can still wobble after being buried in the ground, then the post can be staked down with lengths of twine.

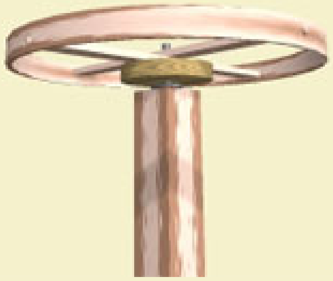

Figure 12: Launch stick with wheel in place.

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Technique...

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Making Large Girandola Frames

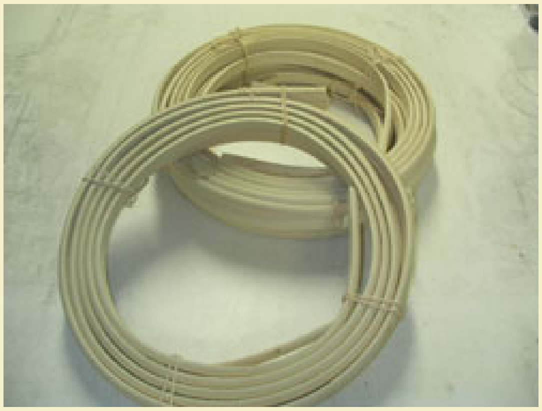
Figure 1: Bundles of 5/8" half-round reed shipped in 24 foot lengths.

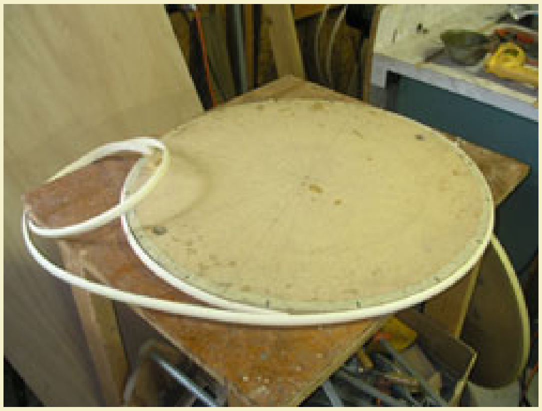
Figure 2: Using a 24" diameter disk to measure out a length of reed for making hoops.

Introduction:
One of the first barriers to entry people come across when moving up to bigger girandolas is the construction of a suitable frame. Small girandolas have a wide variety of simple frames to choose from, such as plastic bucket bottoms, tuna cans, knitting frames etc. As the diameter increases, some materials such as plastic, fiberglass and paper become too flimsy to work well. A typical 24" diameter girandola can weigh from seven to twelve pounds, depending on the payload and number of drivers used. Thus a strong frame must be built in order to support all that weight while sitting on the launch stick, yet still be light enough to enable the girandola to lift a respectable payload without using an unreasonable number of drivers.

Bamboo is the traditional material of choice when building larger girandola frames, or even smaller ones for that matter. The nice thing about bamboo frames is that they are virtually indestructible, thus they usually survive the fall back to Earth so that you can reuse them. The down side to bamboo is that it is a little more difficult to find, and can be extra work to prepare if you can't find it pre-cut into strips of the desired width. Recently it has become popular to cut apart the bamboo poles sold as Tiki torches in many stores. These poles are already split into several strips near the top, so all you need to do is remove the torch basket and split the poles the rest of the way down. However, these poles do not come in seven foot lengths, so you would not be able to construct a 24" hoop without splicing multiple pieces together.

I have tried several different kinds of materials for making larger frames, including laminated poplar strips, fiberglass, flat reed, half round reed, basket hoops and ash splints. Cutting your own wood strips and laminating them together around a form is a bit tedious and the strips often break if bent too far. Fiberglass is messy to work with and results in an overly flexible hoop that is far too flimsy unless you really use a lot of layers without getting air gaps between them. Basket hoops are strong and cheap, but only come in smaller sizes up to about 15" diameter. Ash and even oak wood splints can be laminated together to produce nice looking hoops that are quite strong, but finding them in the 76 inch lengths required to make a 24 inch diameter frame is difficult.

The material I have recently switched to for making the outer hoop rings is known as half-round reed, which is quite cheap, strong, very light, comes in long lengths and is very easy to work with. What I like about the reed as compared to bamboo is that you don't have to split it, the size and shape is very uniform, it takes wood glue well, is easy to splice into a hoop, it has a nice flat surface on one side for attaching drivers, it is cheap, easy to find and very light weight. The reed is flat on one side and round on the other, making it very strong yet still flexible and virtually impossible to break while bending it. The reed comes in rolled up bundles as seen in Figure 1, which is nice because the sticks will already have a curve to them in the direction that you want, removing the need to use forms, water or other methods of bending them into shape. The hoops can actually be spliced and glued without using any type of central holding fixture, allowing you to make many of them at once without having to have a form for each one. The half-round reed used here is the 5/8" size ordered from www.basketpatterns.com for $4.75 per 24 foot bundle. Unfortunately the bundles aren't usually one continuous 24 foot piece, rather two or three separate pieces that add up to 24 feet in length. You can always get two hoops and sometimes three made from each bundle depending on how they are cut.

Because my frames typically land in inaccessible places or get blown apart by the header effect, I don't really know how well they survive impact on landing. It is likely that some of the internal supports will break and need repairs, while the outer hoops will not suffer any damage. The internal framing is made from slats of poplar, which are easy to glue together and quick to assemble. The design of the cross members are quite strong and thus only four spokes are required, making for a very light frame. The finished frame will weigh just under one pound.

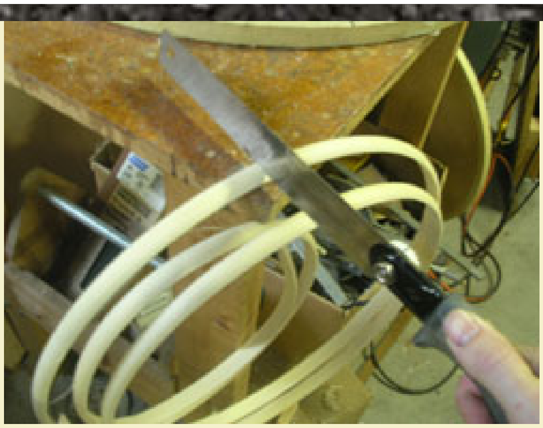

Figure 3: Cutting the reed with a thin pull saw.

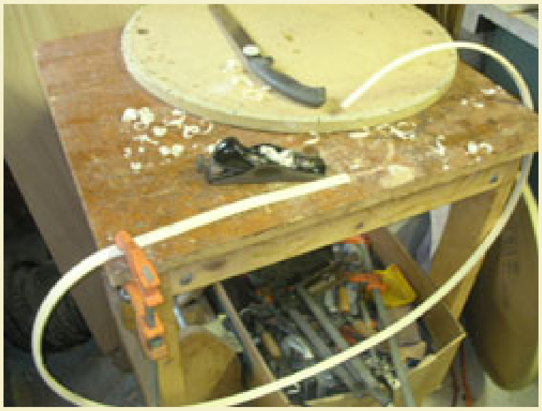

Figure 4: Clamping and planning the rounded side where the ends will be spliced together.

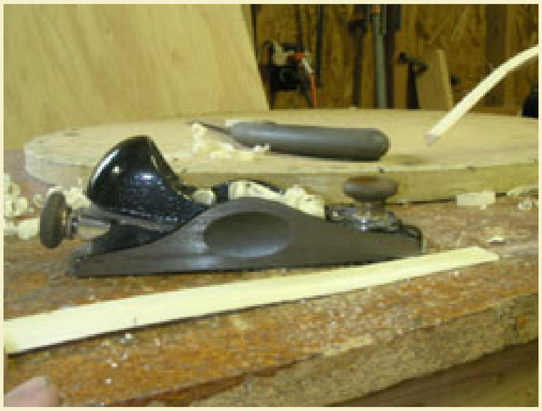

Figure 5: Close-up of gradual 6" long taper.

Construction

While it is not necessary, it is very useful to have a 24" diameter wooden disk cut from plywood or particle board for the purposes of measuring and marking positions on your frame during construction. Figure 2 shows this disk being used to measure out a length of reed for one of the hoops. The reed is tightly wrapped around the disk and then overlapped by about six inches where the pieces will be spliced together. Use a pencil to mark where the ends will be located on the spliced joint. Without the disk, you will need to measure out a two lengths of reed 81-3/8" long, then make a mark six inches from each end. The reed is very tightly coiled, but it can be bent and formed into shape without risk of breaking it. Still, trying to measure a long piece of it accurately will be difficult due to the curve, which is why the wood disk makes this task much easier. Once the length is marked, the reed can be cut using a fine toothed saw such as a pull saw, as seen in Figure 3.

The ends of the reed will be joined together using an overlapping joint that is planed at gradual angles so that the resulting joint fits together flush in one continuous piece. This type of joint is known as a scarf joint, and can be easily made using a block plane as seen in Figure 5. First plane the rounded face by clamping the reed to a work table as seen in Figure 4. Start the slope six inches back from the end, and keep planning until the reed tapers down to less than 1/16" thick at the end. The reed planes very easily, and a sander could probably also be used to create the angled slope.

The opposite end of the reed must be sloped on the flat side, which is a bit more of a pain due to the curvature. Figure 6 shows how the

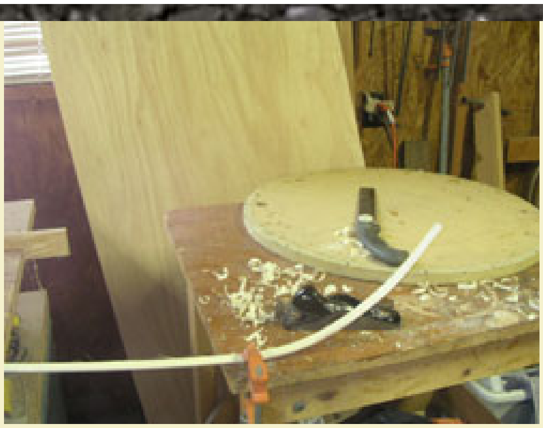

Figure 6: Block planning the flat side of the opposite end.

reed will stubbornly cure upwards while you try to plane it. You just have to force the reed down flat on the table at the same time you are planning it.

Once you have planned both ends of the reed, they should overlap to form a nice joint. Wood glue is applied between this joint and clamped together for drying as seen in Figure 7. The process is repeated for the second hoop, then set aside to dry as seen in Figure 8. The hoops will likely be quite irregular and oblong at this point, but they will straighten out into perfect rings once the internal frame work is completed. You can also shape them by bending in order to work out some of the more drastic irregularities. Reed tends to be somewhat moldable rather than rigidly snapping back into its original shape the way wood or bamboo does.

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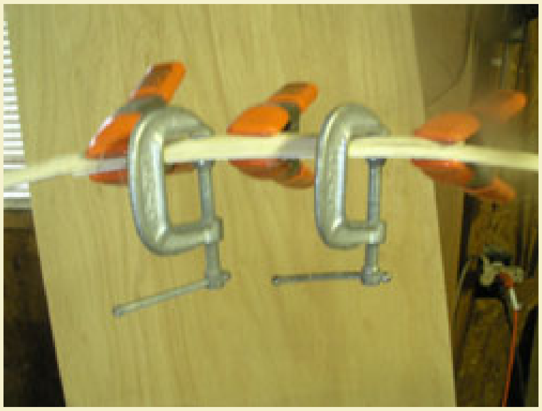

Figure 7: Clamping the ends together to form the overlapping scarf joint.

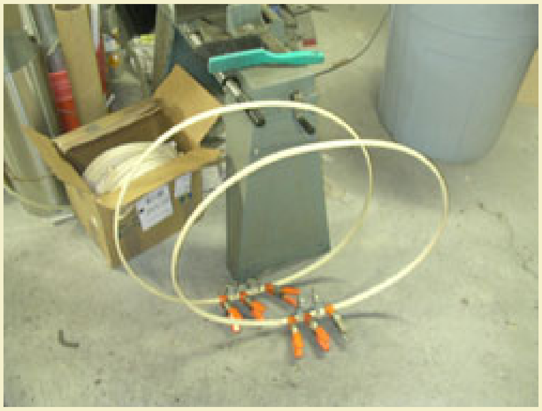

Figure 8: Two clamped hoops waiting for the glue to dry.

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Once the hoop joints are dried, two hoops need to be connected together to form a double set of rings. This effectively produces one thick hoop with a double set of rails for tying the vertical drivers onto. While smaller girandolas can get by using just one ring, the larger drivers used in bigger girandolas need two tie-off points in order to securely fix them at the desired angles. The vertical drivers also become part of the frame integrity themselves, adding considerable support between the two rings to help minimize flexing.

The hoops are connected together using 5" tall strips of poplar cut to a thickness of about 3/16" thick. All of the internal frame members will be constructed from this same material, so it helps to rip a bunch of long 3/16" thick strips from a four foot long board to have them on hand when building more frames in the future.

In order to mark the four positions where the vertical supports will be glued, the wooden disk is again used as seen in Figure 9. The disk not only serves to hold the hoop into an even circle when marking the connection points, it serves as a template for marking both frame connection points and driver connection points. It is necessary that the exact center point of the wood disk be known so you can measure out the proper angles using a protractor. A set of lines crossing at right angles are first marked on the disk, which indicates where the frame spokes will be. A second set of tick marks are placed every 22.5 degrees, resulting in 16 evenly spaced points where the drivers will be located. Note that the frame markers are located at the midpoint between two driver points, insuring that the frame does not obstruct driver placement. If more than 16 drivers are required, it is easy to visually align more drivers between the first sixteen drivers. Sixteen is about the minimum number of drivers you would need for a girandola this big, while 28 is about the maximum number the frame will hold.

Once your hoop is slipped onto the marker guide, use a pen to transfer alignment marks onto the frame where the four vertical supports will be located. It is a good idea to align the hoop so that one support will fall directly at the midpoint of the scarf joint, even though the joint is very unlikely to ever come apart unless the frame gets wet. When marking the bottom ring, I like to take a different colored marker and mark all the points where the drivers will be located as well. For the top ring this is not necessary, as the top points will be in a slightly different spot due to the angle of the drivers when they are attached.

Once the hoops are marked, wood glue and spring clamps are used to quickly attach the hoops together using the vertical supports.

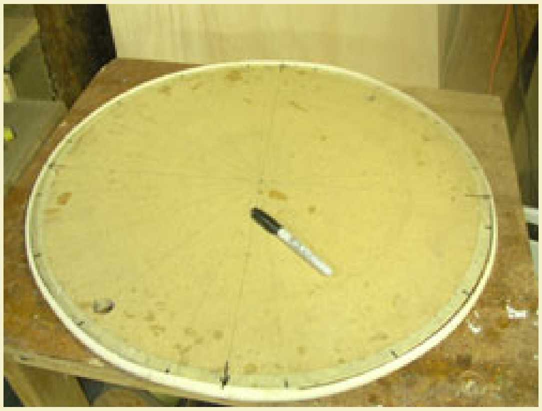

Figure 9: Using the disk template to mark cross member connection points.

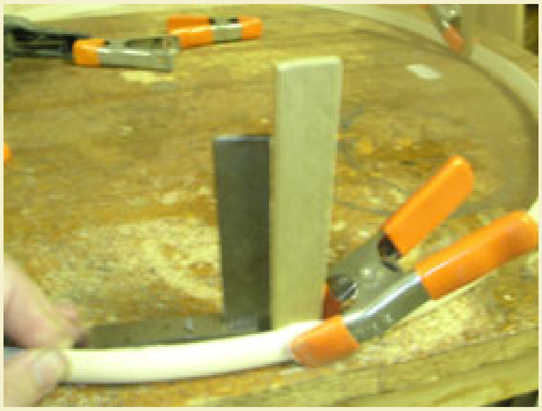

Figure 10: Aligning and gluing the vertical supports that connect the two rings together.

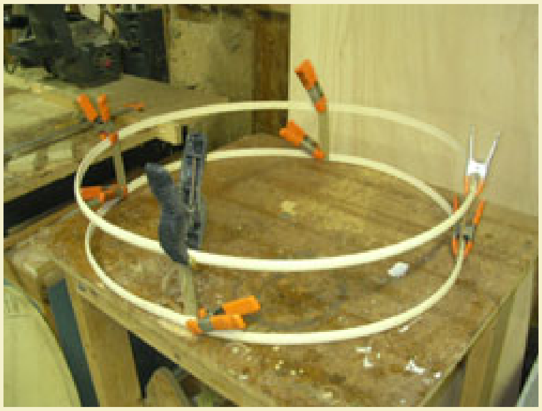

Figure 11: Using spring clamps to hold both ends of all four connectors until glue dries.

Figure 10 shows how a right-angle gauge is used to make sure the vertical supports are properly aligned before attaching them to the upper hoop. Figure 11 shows all supports in place with spring clamps at both ends of each support. For the purpose of creating a more balanced frame, it is a good idea to locate the scarf joint of the top hoop on the exact opposite side as the scarf joint on the lower hoop.

After the glue has dried, a small hole must be drilled through each end of the vertical supports at the midpoint of the frame, as seen in Figure 12. The diameter of this hole should be just a hair larger than the thickness of your frame members. So if you are using 3/16" thick wood slats, then the holes should be 7/32" diameter. These holes are used by the pins that will be formed on the end of the frame members, which will create a strong mortise and tenon type joint that will still hold even if the glue cracks during use.

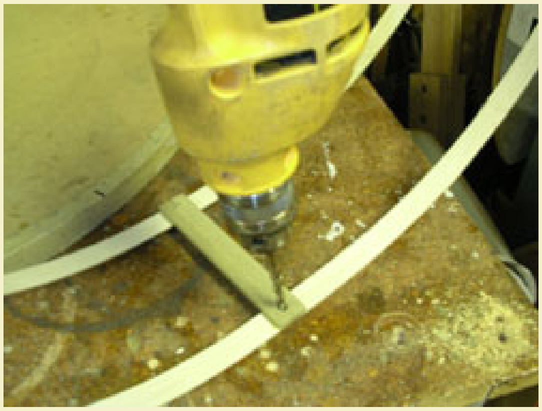
Figure 12: Drilling holes through the vertical cross members where the frame pins will connect into.

The central hub for the frame spokes is made from two blocks of 2" square poplar. Poplar is used throughout the frame for its tight grain, absence of knots, light weight and resistance to splitting. Pine is lighter, but splits too easily to be used reliably for the hub blocks.

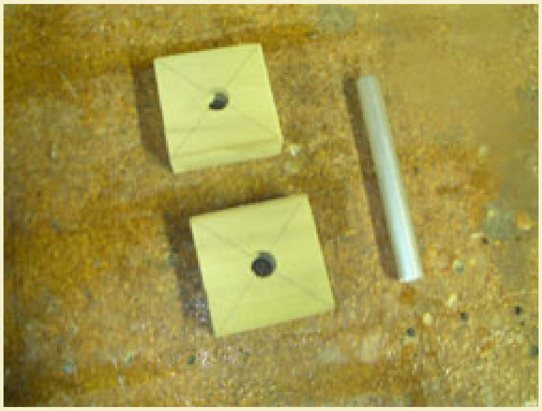
Figure 13: A pair of 2" square hubs made from poplar.

There is an upper hub block and a lower block, with a hollow aluminum rod sandwiched between them. The aluminum axle tube is 1/2" O.D. and 3/8" I.D. with a length of 4-1/2" , which is cut from a 36" long tube stock sold in many hardware stores. The center hole in the wood hubs should be drilled half way using a 1/2" diameter bit, then finished the remainder of the way using a 7/16" bit. This way the axle tube can be locked into position between the blocks without sliding up or down.

The corners of the hub blocks need to be slotted so that the frame spokes can be glued solidly into them. Use a piece of frame scrap to mark the width of the slots that are to be cut, as seen in Figure 14. The slots should be cut 3/4" long into the blocks using a band saw as seen in Figure 15. After cutting the left and right edges of the strip to be removed, the final back cut can be done by making many tiny angled cuts or using the side cutting action of some blades when pressed sideways.

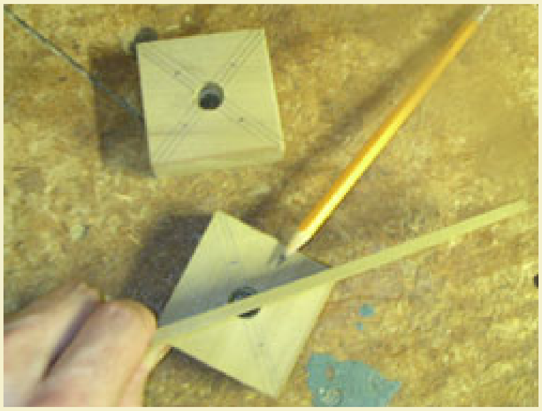
Figure 14: Using a piece of the frame members to mark the slot cutout widths on the hubs.

Once the four slots are cut, the final step is to drill a small hole equal in diameter to the holes you drilled through the side of the frame hoops in Figure 12. The hole is drilled at the center point from the bottom of the slot all the way through to the axle hole. Figure 16 shows how a wood clamp can be used to hold the hubs on their corners when drilling this hole on a drill press. The frame spokes that fit into these slots will have a tenon pin that fits into this hole, reinforcing the joint so that it will not break even if the glue cracks under stress.

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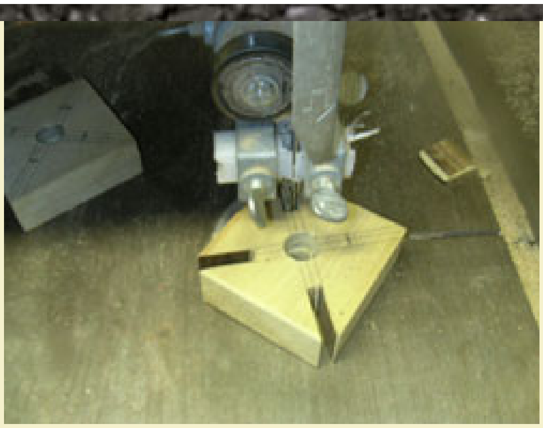

Figure 15: Cutting out the frame junction slots using a band saw.

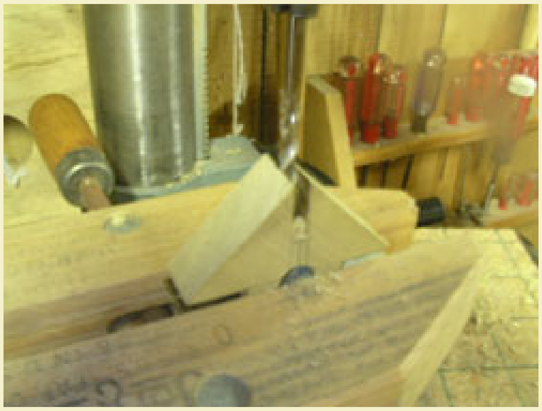

Figure 16: Drilling mortise holes for the frame pins to connect into.

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Making Large Girandola Frames...

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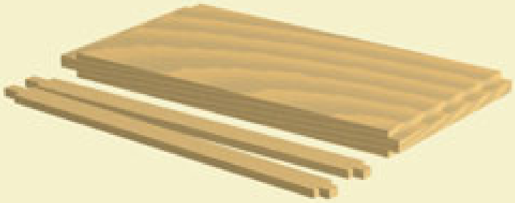
Figure 17: Notching the edge of a solid board before cutting the frame spoke strips from it.

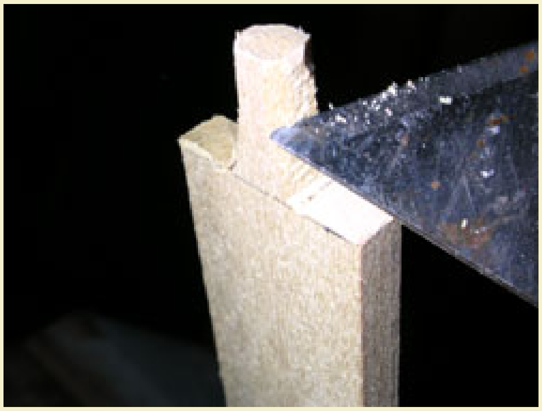
Figure 18: Using a utility knife to round out the square pegs so that they will fit in the mortise holes.

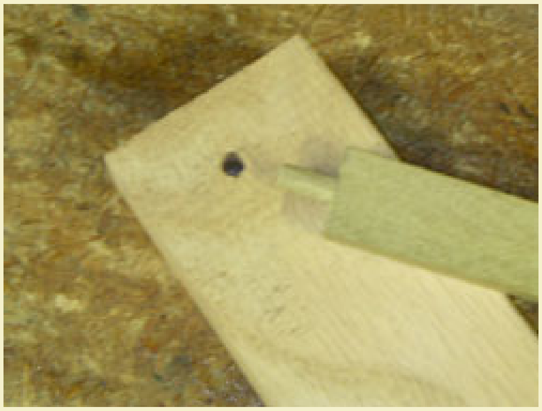
Figure 19: Using a test hole in a scrap of wood to make sure each tenon will fit before installing into the frame.

Next you will need to produce two sets of four spokes that connect from the center hub to the outer rings, for a total of eight spokes. These spokes are made from the 3/16" thick poplar strips that are ripped from the edge of a standard 3/4" thick board. The ends of each spoke will reduce down to a round pin that fits into the holes you drilled in the outer rings and in the hubs. The diameter of this pin will equal the thickness of the slats, while the length will be 1/4" on the side that plugs into the hub and 7/16" on the side that plugs into the outer rings. The outer pin is longer because it runs through both the vertical ring supports and all the way flush with the outside of the rings.

The pins are created by first notching out square pins and then rounding them off by carving the corners off with a utility knife as seen in Figure 18. While you could use a band saw to notch out the spokes on each end, a faster way is to notch a much wider board and then rip the spokes from it one by one, as seen in Figure 17. Start with a 1x6 that is 12-1/16" long, then use a router or dado blade to rabbit the top and bottom of each edge to a depth of just a hair over 1/4". This way you only have to notch one large board to get many smaller notched strips.

Once you carve off the corners of the square pegs so that they look roughly circular, it is a good idea to test fit them into a 7/32" hole drilled in a piece of scrap wood as seen in Figure 19. This way you find any binding pins that need further carving before they are covered with glue!

Now you are ready to glue all the pieces together. I usually test fit all the parts before actually gluing them, just in case something needs more trimming. Start by gluing three spokes into the hub, applying glue to the sides of the slats as well as all around the pin. It is easiest to just pour a small pool of glue on a scrap of cardboard and just use your fingers to brush the glue onto the ends of the spokes when doing this.

When installing the lower frame, make sure the hub is orientated with the larger hole facing upwards, as seen in Figure 20. Glue the three spokes into the frame, then glue the fourth spoke into the frame first before trying to insert it into the last hub slot. You will have to bend the frame out until the spoke is able to drop down into the hub slot, then seat the pin into the hole to complete the lower portion of the frame.

The upper section of frame is completed in the same way, only with

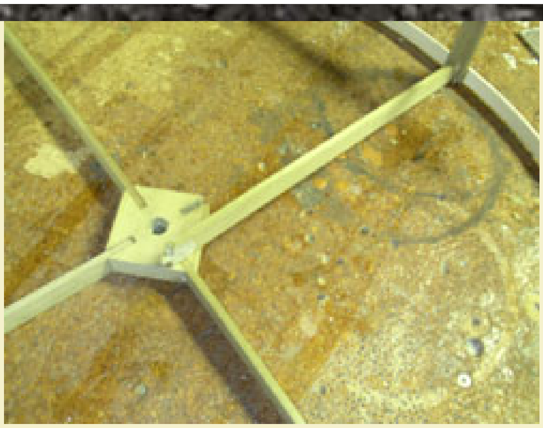

Figure 20: After installing three spokes, the final one is inserted into the hoop and then pulled back and dropped into the slot.

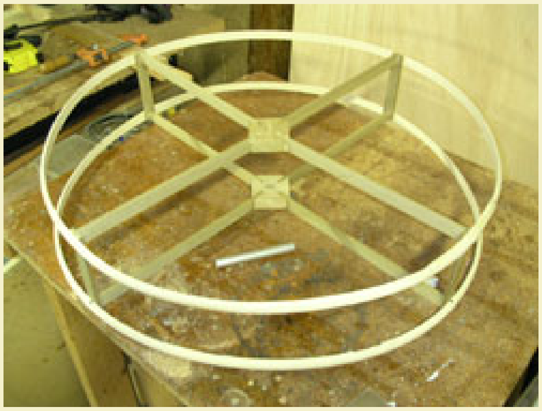

Figure 21: After the top and bottom spokes have been assembled, the axle pin is seated into the hubs.

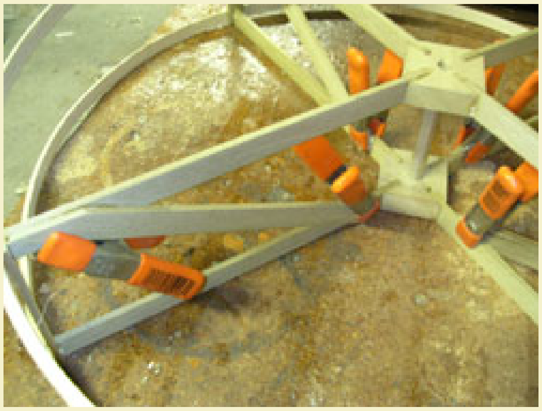

Figure 22: Diagonal braces are glued in place and held with spring clamps until dry.

the larger hub hole facing downwards. With the two frames assembled, the rings will be forced into a nice round shape as seen in Figure 21. At this point you will need to insert the aluminum tube between the two hubs. The frames will easily flex outwards to allow the tube to be pushed in place. There is no need to glue the axle tube in place, it will not be able to fall out once the upper and lower frames are tied together with the diagonal bracing.

If the frame were used without further bracing, there may be some sagging of the cross members when the completed girandola is resting on the launch stand. This is because the majority of the weight on a girandola resides on the outer perimeter rather than at the center. This weight will stress the cross members when supported at the center point, as is the case when it is resting on the launch stick. A fully loaded girandola could possibly crack the glue joints and compromise the frame in this scenario.

The addition of diagonal bracing as seen in Figure 22 will drastically increase the strength of the frame without adding much additional weight. Simply take some pieces of extra frame slats and trim the corners so that they don't stick up above or below the spokes when glued in place. One spring clamp on each end is all it takes to quickly glue these supports in place. The angle is not arbitrary, the braces must run from the bottom hub up to the upper ring in order to provide the strongest support when resting on the launch stick.

With the diagonal supports glued and clamped, rest the frame on a flat surface and make sure all edges come in contact with the table. If the frame is warped a little, placing weights on the frame can help flatten out the frame and insure that it stays that way when the glue dries.

The finished frame should weigh about 450 grams and take less than 4 hours to construct. This gives you a light weight frame that can be made on short notice without the need for tarred string, split bamboo or special forms.

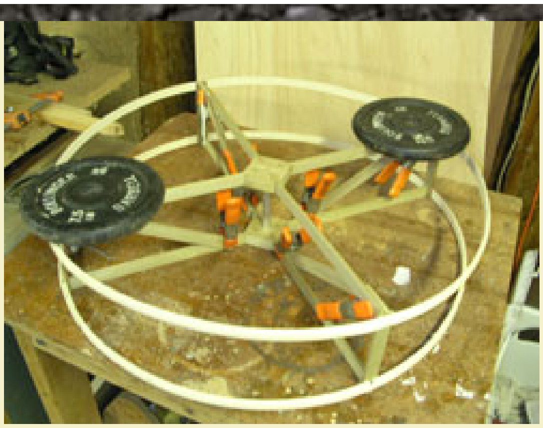

Figure 23: Using weights to make sure the frame lies flat on the table while the diagonal braces are allowed to dry.

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Tool Tip...

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Making Girandola Frames

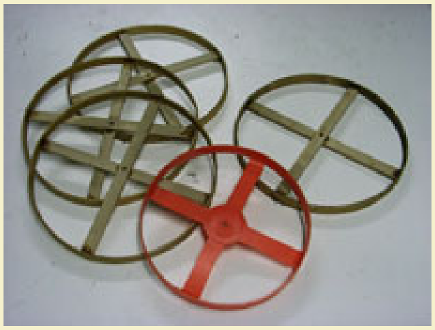

Figure 1: Assorted girandola frames.

Introduction:

When setting out to build your first girandola, the first problem most people run into is finding a suitable frame. The frame needs to be light, fire resistant, the desired size and ideally able to withstand the drop from several hundred feet without breaking.

Three methods of building simple single-ring girandola frames are presented here. These are suitable for small girandolas in the 8" to 16" range that do not require two rings in order to support the drivers. As girandolas become larger, it becomes necessary to use a more sturdy frame design that allows the drivers to be fastened at two points instead of just one.

Method 1:

The quickest and easiest method to fabricate a durable and reusable girandola frame is to make one from the bottom of a five gallon plastic bucket. I am not sure who first conceived of this idea, but Tom Perigrin also mentions this method in his book Introductory Practical Pyrotechnics.

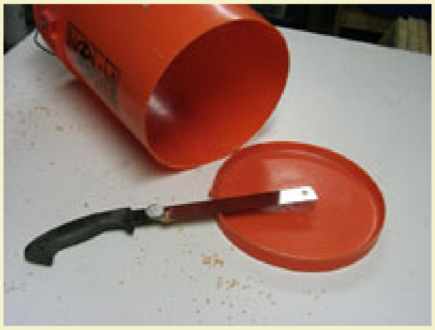

Figure 2: Sacrificing a 5 gallon bucket.

Plastic bucket frames have the advantage of being very durable, easy to make and cheap (assuming you have a supply of free buckets). The disadvantages are that the plastic is not as fire resistant as wood, nor is the plastic as sturdy as wood. Another disadvantage is the size limitation, as the material is too flimsy to ever be used for larger frames (assuming you could ever even find larger buckets).

Begin by cutting the bottom off of a five gallon bucket as shown in Figure 2. The cut is made at least an inch from the bottom, this way you will have a plastic rim to increase the rigidity and provide a surface for attaching drivers to. I find that the best tool for making the cut is a thin kerf Japanese type hand saw.

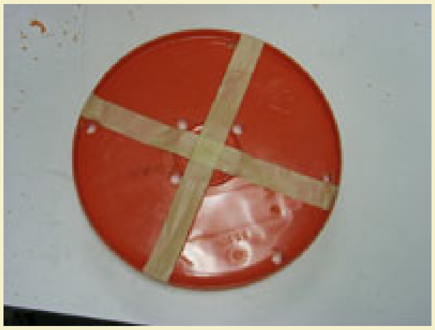

Figure 3: Holes and tape for aid in cutting out quarter panels.

Once the bottom is cut out and the edges are deburred and cleaned up, make an X across the center of the bottom using one inch wide masking tape, as seen in Figure 3. This will be your guidelines for cutting out the excess plastic from the frame.

The four quadrants must now be removed, since the wheel must be made as light as possible. This can be done using a sharp utility knife, but it is easier to use a saber saw if you have one. Note the half inch holes drilled at various spots to allow a saber saw blade through the plastic when beginning each cut (see Figure 3).

Once the plastic is removed, the wheel is basically done. Remove the tape, clean up the burrs on the edges with a utility knife and finally drill the desired size hole for your launch pin in the center.

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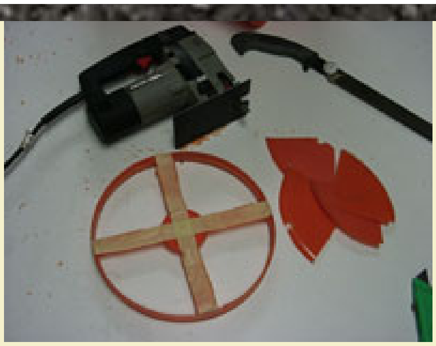

Figure 4: Completed frame ready for deburring.

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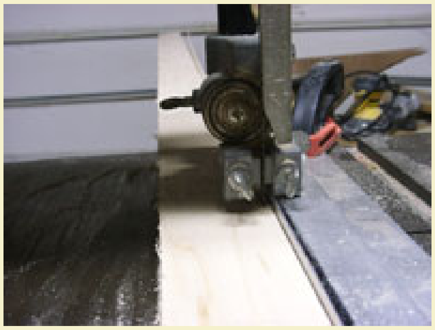

Figure 5: Cutting thin strips of poplar with a bandsaw.

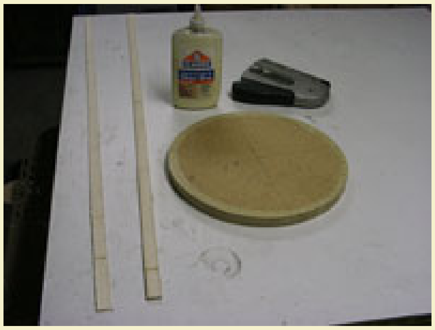

Figure 6: Two thin strips ready to be stapled onto former.

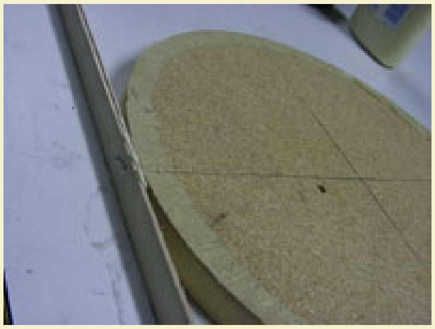

Figure 7: Stapeling halfway overlapped strips to frame at midpoint.

Method 2:
If you are brave enough to attempt making your own hoops, then the first thing you will need is a band saw to cut the thin strips (unless you can find thin strips already cut). The strips need to be about 1/16" thick and made from a light yet flexible wood such as poplar. Using pine or cedar can be frustrating, since these woods tend to break when bending them around the former. Oak bends well, but is also rather heavy. Poplar seems to be a good tradeoff between weight and strength.

Caution: cutting thin strips on a band saw can result in severe profanity! The slightest bit of blade walking can ruin your strip mid cut, which will then require you to reface your board on a table saw or planer to get the edge straight again. I didn't say this was going to be easy! Just make sure your stop blocks are in good shape and butted right up against each side of the band saw blade. It also helps to be using a wider blade, which tends to walk less.

A circular form made from something like particleboard is used to bend the strips around. The edges of the form should be covered with masking tape to prevent the hoop from accidentally getting glued to the former. The form used in Figure 6 is one foot in diameter.

One you have the strips made, mark the center of one and apply wood glue down half its length. The second strip is now placed on top of the glue such that it overlaps the first strip by half. This assembly is now stapled to the form right at the midpoint, as seen in Figure 7. The staples should be about 1/2" so that they penetrate both strips and far enough into the form to hold things together.

Next the form is placed on end to that it pins the stapled joint down onto the table. The two strips are bent half way around and held down with more staples, as shown in Figure 8. While holding the strips in this position, apply some glue along the remaining length of the bottom strip.

Now comes the hard part (as if it hasn't been hard enough up till now). The top strip needs to be curved down around the form until it meets itself at the joint. If the strip is too long, it may be trimmed with scissors. Once it is butted up against where it started, the other strip is pulled up over it and stapled into place. The second strip should form another butt joint at the top. Trim as necessary to minimize any gap or eliminate overlaps.

If you have not thrown the entire assembly across the room by now, then your patience is admirable and the results should look like Figure 9.

Once the glue dries on the laminated hoop, the staples are pried out with a screwdriver and the hoop is removed. It helps to have guidelines on your form so that you can mark the four points on the hoop where the cross members will connect.

You will need to drill a 1/4" hole through the frame where the spokes will attach. Due to the two weak points in the hoop where the strip seams are, it is best to make the cross members connect where these seams are located in order to strengthen them. The frame will not flex at the points where the cross members attach, so this is the best place to locate any weak spots.

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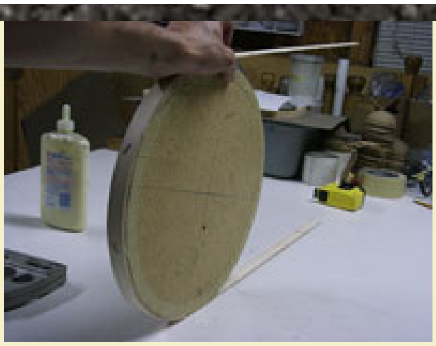

Figure 8: Strips are bent and stapled around former so that the seam for each strip lies directly accross from each other.

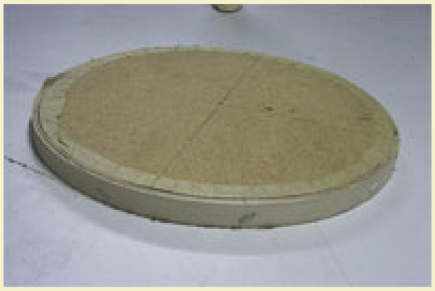

Figure 9: Strips allowed to dry on former, then staples are removed.

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Making Girandola Frames...

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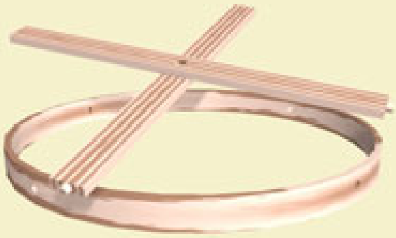

Figure 10: Fitting out the cross members.

The cross members are made by shaving 1/8" or 3/16" strips from 3/4" thick material using the band saw again. These are then cut to the length of the outside diameter of the hoop. Each end of the two cross members must then be notched and trimmed with a utility knife so that you get a round tendon that will fit into the holes you drilled in the hoop. The length of this tendon should be equal to the thickness of the hoop, which should be a little over 1/8".

Finally, the ends of the cross members are glued and the point where they cross over each other at the center is also glued. The pieces are now snapped into place and allowed to dry. The pivot hole at the center is drilled after all the glue is dry.

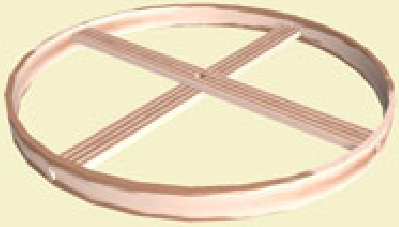

Figure 11: Finished wheel.

Method 3:
If the previous method of making frames seems too difficult, then it probably is. Another method for making high quality wooden frames uses wooden hoops that may be purchased from art supply stores and are usually found in the knitting section. The hoops are sold in pairs, with one being adjustable and the other being solid. You really just want the solid one but you have to buy both. This is a more expensive way to make the girandola frames, and they are slightly heavier, but it saves you the trouble of having to make your own hoop. The hoops also come in a variety of sizes, so you are not limited to just one size as in the case of the five gallon bucket method.

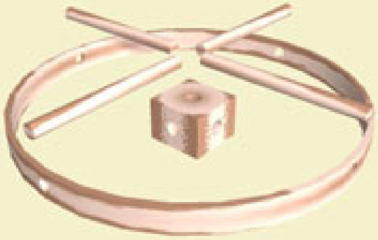

Figure 12: Stitching frame and dowel rods with 2x2 hub.

One you have your hoop, you will need to get some dowel rods to use as the spokes. The diameter of the dowel rods should be half the height of the hoop frame. Thus if your hoop is 3/4" tall, you will need four 3/8" dowel rods equal to the radius of your hoop.

You will also need a central hub for the dowel rod spokes to plug into. This can be made by cutting off a 1" section of spruce 2x2 material. You can leave the hub square, or you can shave down the corners to reduce the weight. It is easier to drill all the holes while the hub is still square. You will need holes in four adjacent sides where the dowel rods get glued in, and one down the middle that will loosely slip over your launch pin. You will also need to drill holes through your hoop at the four points where the spokes connect. A drill press is the ideal tool for making these holes, since they need to be very straight.

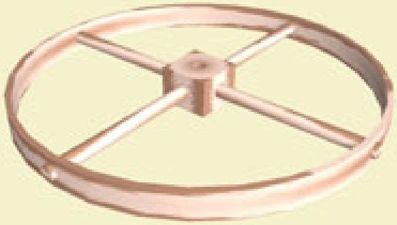

Figure 13: Finished wheel using store-bought components.

If you are using a large hoop, you may need more than four spokes, which will require you to fabricate a pentagon or hexagon shaped hub. If this sounds like too much work, a segment of 1-1/2" round dowel rod can also be used in cases where more than four spokes are needed. More skill in marking and drilling each hole will be required when using a dowel rod as the hub.

Figure 12 shows all the components ready to be glued together. The dowel rods can stick out beyond the frame when glued and then sanded down later. Note that a stronger joint is made by not drilling the spoke holes all the way into the center of the hub, such that the launch pin hole is not intersected by the spoke holes. This also helps reduce problems of glue spilling down into the center hole and decreasing it's diameter. Another method to prevent this problem is to drill the center hole only after the entire assembly has been glued together.

Summary:

The three methods shown here have different tradeoffs between cost, ease of fabrication, resistance to fire and weight. The second method produces the lightest wheel, weighing in at about 80 grams if material is minimized, but requires the most tools and skill to make. The bucket wheel is slightly heavier, but is easily made and will withstand a fall from any height. The wheel made using method three is the most expensive and heaviest method, but is the strongest wheel of the three. Hopefully the reader will find a workable design based on his requirements, woodworking skills and available materials.

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Beginner Project... **Page 1**

1-1/4" Microstar Gerbs

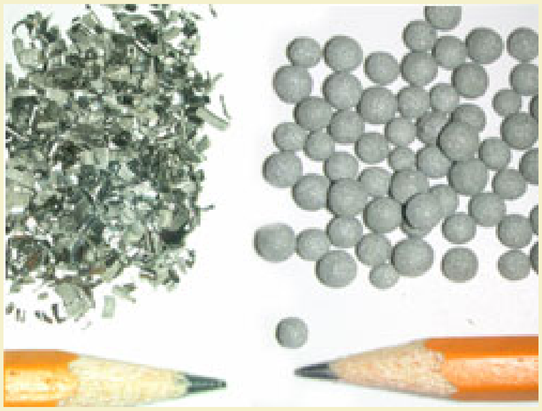

Figure 1: 10-20m titanium turnings and micro stars.

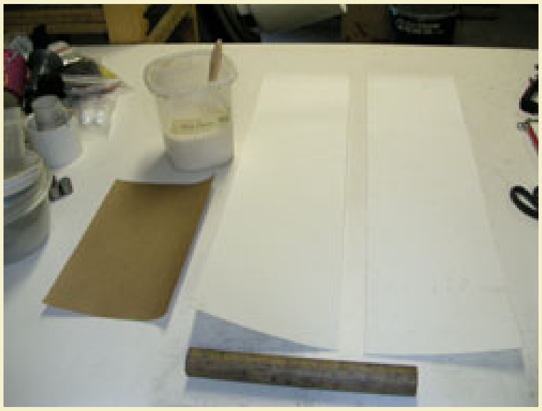

Figure 2: Rolling the casing from poster board.

Materials:

- (1) 44" long x 7" wide poster board
- (1) 11" long x 7" wide 30lb kraft
- (1) 11" long x 5" wide 30lb kraft
- (1) 3" long visco or black match
- fire clay (bentonite)
- gerb composition

Introduction:

Gerbs, also known as fountains, are simple tubes of pyrotechnic composition that spray a plume of sparks from a hole in one end. They are among the simplest firework devices to construct, thus they make a good starting point for beginners. The gerb shown here is actually a bit more advanced than a typical gerb, due to its larger size and microstar requirement, but the same technique applies to all gerbs.

Most gerb compositions utilize some type of metal particles in the mixture in order to obtain good spark height. While coarse charcoal can be used to create a larger plume when making a gold fountain, the light weight of charcoal particles does not allow the pieces to be thrown as far as will metal particles. A better choice for a gold gerb is to use steel filings or iron turnings. Filings are generally granular type particles, like sand, while turnings are fragmented strips of metal that usually result from lathe or milling operations. If you have access to a machine shop, you may find all sorts of metal turnings for the taking just sitting in the catch trough under a lathe. Some people have also successfully used brake turnings obtained from auto repair or brake shops.

The most common metals used in gerbs are steel/iron, titanium and aluminum. The larger the metal particles are, the higher they will be thrown and the longer they will burn. Steel and iron produce a gold branching type of spark that is a brighter yellowish color than charcoal sparks. Titanium produces bright white sparks with good duration, and is the metal of choice for silver gerbs. Aluminum also produces bright white sparks, but tend not to go as high as titanium and also seems to have a shorter burn time. Larger sized flake aluminum is ideal for creating a fire-fly effect when used in a charcoal-intense base formula.

Microstars are tiny bits of color burning composition that are mixed in with the gerb formula in order to produce colored sparks, since metal particles can only produce shades of gold and silver. Since star compositions burn faster than metal particles, the microstars are substantially larger than the tiny metal particles. Thus the colored sparks created by micostars are less dense than the gold or silver sparks produced by metals.

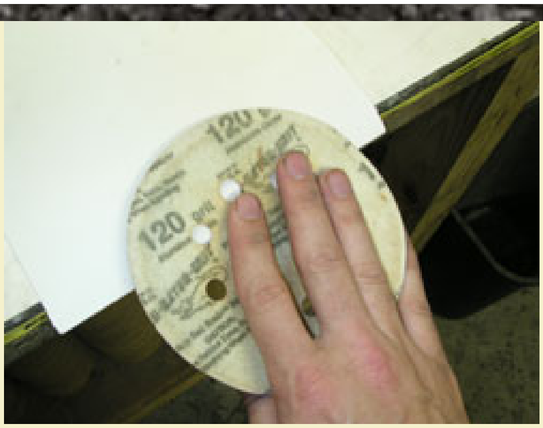
Figure 3: Sanding the inside edge to a taper.

The gerb described here is a bit on the large side compared with consumer gerbs, but I figure if you are going to build your own fireworks then you might as well make them bigger and better than anything you could just buy in the store. This gerb will shoot silver sparks and microstars up to about 30 feet, with a burn time of around 16 seconds. The gerb also has enough thrust to make it a unique driver for wheels and other revolving set pieces.

Rolling the Case

A strong casing with an inside diameter (I.D.) of 1-1/4" with at least a 3/16" wall thickness is required to build this gerb. The length of the casing can vary depending on how long of a burn time you want. The case used here has a length of seven inches, which should give you a duration of about sixteen seconds.

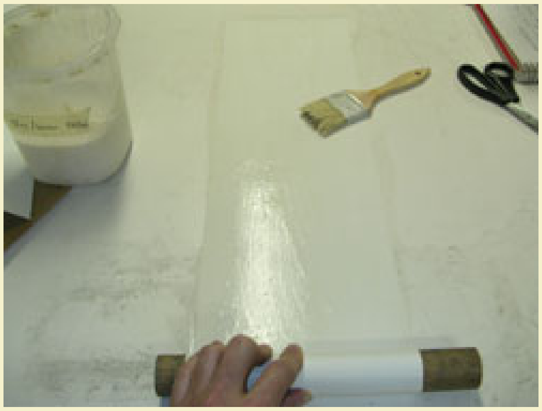
Figure 4: Coating one side with 50/50 white glue/water.

Since good quality tubes in larger sizes can be hard to find or expensive when you do find them, it is often easier just to roll your own unless you need a lot of them. A very strong casing can be made from two strips of poster board paper that are 7" wide and 22" long, with the paper grain running along the width. Figure 2 shows the components required to roll your case, which include a 10" long x 1-1/4" wooden dowel rod, the poster board strips, an 11" long x 7" wide finish wrap of 30 lb kraft and a mixture of 50/50 white glue and water.

Before rolling the first strip, the edge is prepped by sanding it to a taper as seen in Figure 3. This is done to prevent the thick paper from leaving an air gap that runs the length of the tube, which can cause sparks to skip down the side of the powder column and blow the gerb up. The edge is beveled so that it will lay flat inside the case when rolled.

Figure 5: The final two turns of 30lb kraft.

The first turn of paper is rolled dry around the case former and held in place while the remainder of the paper is painted with the 50/50 glue mixture as seen in Figure 4. After the first strip is almost completely rolled up, the second strip is overlapped slightly onto the first and painted with the glue mixture as before. The second strip is then rolled up and the final kraft outer wrap is overlapped, glued and rolled up to finish the casing. Using the thin kraft for the last two turns helps hold the tube together so that the thicker paper can not unravel.

The finished case is put aside to dry completely before proceeding.

The Composition

The formula for most gerbs involves a black powder base with additional charcoal added to regulate burn rate, then the addition of metal dust according to the desired effect. The formula used here uses 60% ball milled meal made with home-made spruce charcoal. The fine milling and spruce charcoal creates a fiercer burning fuel than if commercial air-float is used, and an additional 10% commercial air-float is added to slow the mix down some. If you make your meal from commercial air-float, ball mill it less or just end up with a weaker meal than usual, you can decrease the amount of additional charcoal added.

There are three spark producing ingredients added for effect only.

These are the coarse charcoal, the titanium flakes and the microstars. The coarse charcoal is not really necessary when making a titanium gerb, since you won't be able to see the orange sparks against the bright white sparks, but I just add it anyway so that if you want to make a good fire-fly formula then all you need to do is substitute the titanium flakes with aluminum flakes.

The microstars should be less than 3/16" in size, either rolled or cut. It is easier to make microstars by rolling small cores in a star roller, or even use the core-less method of making them described here. The stars shown in Figure 1 were made from husked millet as the rolling core, which is a very small seed that does not consume much volume compared with other core types. I prefer to use perchlorate/magnalium type star formulas for their brightness and longer burn time, which helps make the microstars stand out more even when surrounded by bright white sparks. Since the microstars will be embedded in the gerb driver composition, there is no need to prime them.

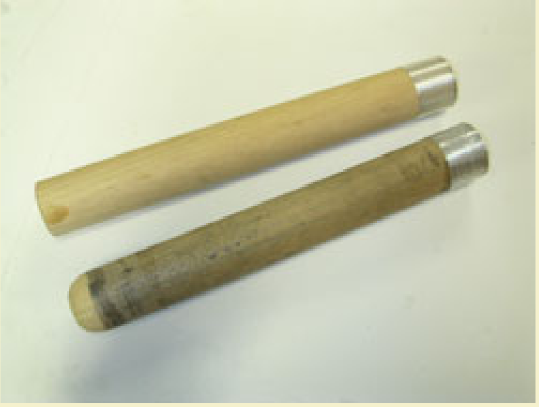
Figure 6: Wooden dowel rods used as rammers.

Loading the Case

The only tools needed to load this gerb are two 10" long rammers that can be easily made from 1-1/4" diameter wooded dowel rods. Oak dowels are preferred, since you will be beating on them pretty hard with a hammer. I like to apply several turns of fiber reinforced tape around the ramming end to help keep the ends from splitting as they mushroom out over time. The rammer used to drive the clay plug has a rounded end, which produces a curved surface on the inside end of the plug. This curve is necessary to guide the microstars out of the vent hole during display, which is especially important if the gerb will be fired from a horizontal position. I used to make these gerbs with just a flat ended rammer for the clay plug, and could never figure out why the microstars disappeared when the gerbs were used as horizontal drivers on wheels. When fired straight up they worked fine, but when fired horizontally the microstars just disappeared! It turns out that without the curved inner plug surface, the stars get trapped inside and never make it out if the gerb is fired on it's side!

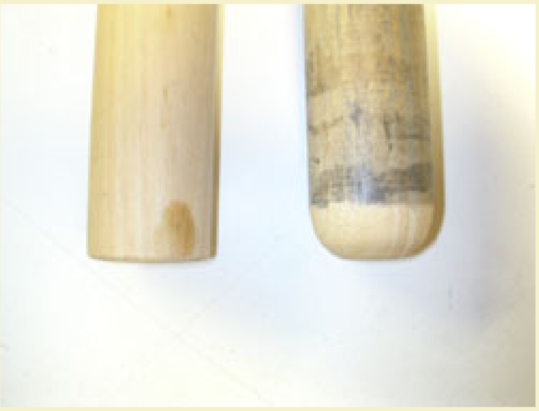
Figure 7: The plug forming rammer has a rounded tip.

No special nipple is required to load this gerb. The vent plug is rammed first, and is flush with the end of the gerb tube. Three level table spoons of powdered clay are required when using the rounded plug rammer. If you opt for a flat ended plug rammer, then only two level table spoons are required. Figure 8 shows the clay being loaded into the tube with a funnel.

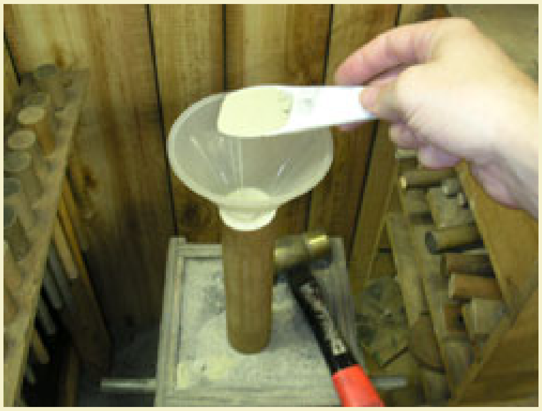
Figure 8: Making the clay plug.

Once the plug is rammed, the gerb composition is rammed in increments of one heaping table spoon. Figure 9 shows how just how much heap I use here. Each increment must be rammed pretty hard due to the large diameter of the rammer. The larger the diameter is, the less compression you get with each whack of the hammer, since the force is being distributed over a larger surface area. The increments are rammed one at a time until the powder column reaches about an inch from the top of the tube. The bottom end plug is then rammed from two table spoons of powdered clay to finish off the gerb.

The exhaust hole is now drilled in the first clay plug that you

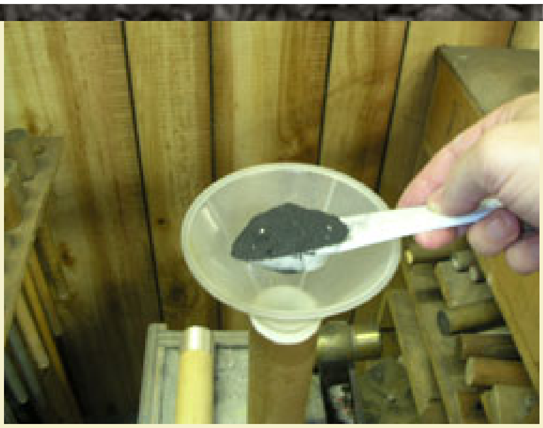

Figure 9: Ramming the driver composition.

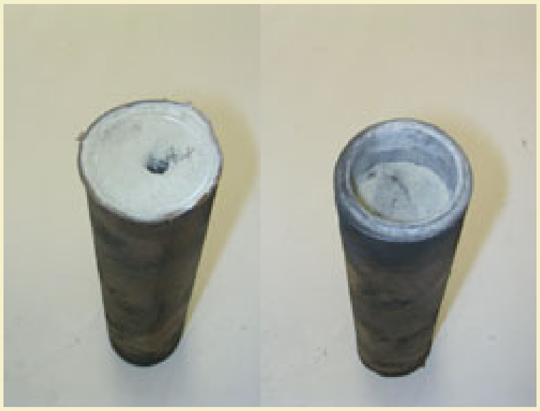

Figure 10: The top (left) and bottom (right) plugs.

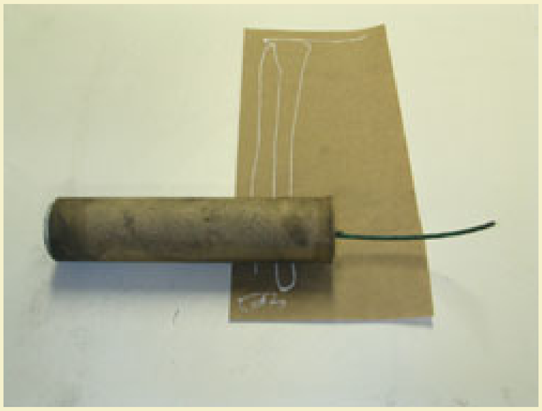

Figure 11: Fusing and nosing the finished gerb.

rammed, as seen in Figure 10. This hole should be 1/4" diameter and run only deep enough to just expose the powder inside. Because the gerb composition contains metal, DO NOT use a power drill to make this hole. The best way is to hand twist the hole in a drill press by pulling down on the press with one hand while twisting the chuck with the other. Note that a special base nipple could be fabricated so that this hole is automatically formed when the end plug is rammed. To keep the tooling simple for the beginner, this hand drilling method will work just fine.

Fusing and Finishing

The gerb is finished by fusing the hole with a doubled-up stick of black match or Visco type safety fuse. It is important that the fuse wedges tightly into the hole so that it will not easily pull out. Two turns of light-weight craft paper is wrapped around the fuse end and onto the fuse as seen in Figure 11, a process which is referred to as "nosing."

This gerb generates a respectable amount of thrust, thus it must be securely anchored when fired. One method is to tie pointed sticks to the side and stake them into the ground. Holes can also be bored through plywood platforms so that the gerb can be inserted and glued in place.

The photograph above shows a group of three gerbs being fired in competition during the Florida Fireworks Festival of 2003. These gerbs contain crackle stars as the microstars, which can be seen as the bright flashes scattered throughout the spark plume.

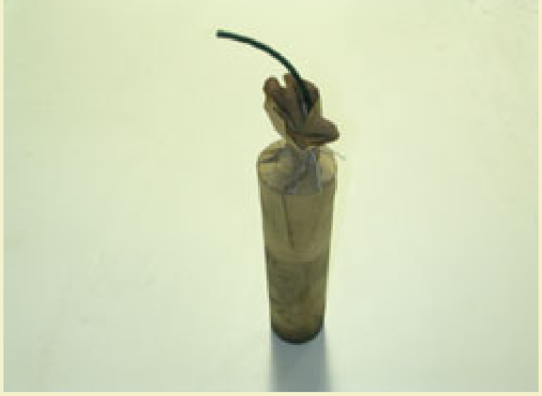

Figure 12: The finished gerb.

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Beginner Project... **Page 1**

Smoke Bombs

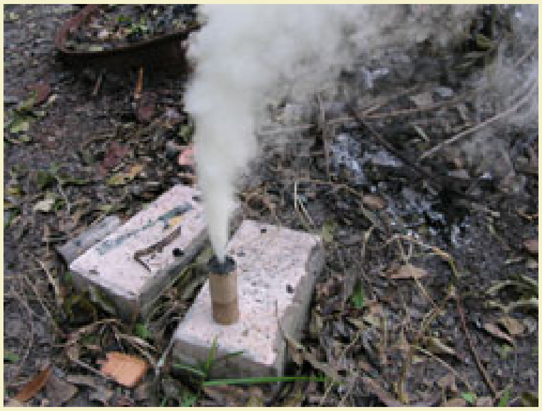

Figure 1: White smoke spraying from a smoke bomb.

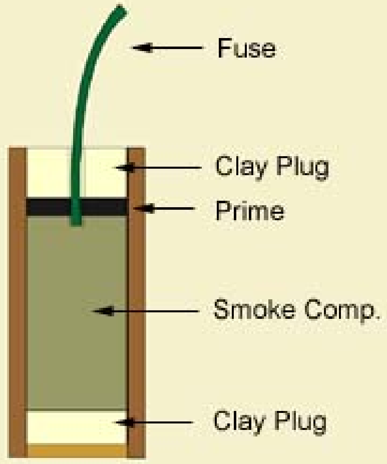

Figure 2: Cutaway showing smoke bomb components.

Introduction:
This is the first of a new series of articles intended for readers who are just getting started in pyrotechnics. The goal is to produce hands-on projects that are simple to build, require only small amounts of composition and require only minimal special tools to make. While the items described still may be of interest to more advanced builders, the experience level of the reader is assumed to be little to none.

Smoke Bombs
Many times smoke is an undesirable side effect of fireworks which tends to get in the way or obscure the display from viewers. However, as a novelty item, smoke bombs can be a fun daytime effect. The type of smoke bomb described here produces thick clouds of white smoke with a sulfurous odor that, while some find unpleasant, I think smells quite good! Perhaps the smell simply reminds me of my youth when I used these long-burning smoke generators for all kinds of mischief.

A smoke bomb thrown into a dense leafy bush can create the appearance of fog oozing from within. Throw one down a sewer grate and watch the fog spill out onto the street from below. A smoke bomb in a trash can create a "can of smoke" effect for Halloween. On a still night, several smoke bombs can be used to create an artificial layer of fog that hovers above the ground for quite a while. Care must be taken to avoid throwing the smoke bomb into flammable material however, as the initial ignition of a smoke bomb projects a blow-torch like flame for several seconds before the smoke phase starts. A smoke bomb thrown into a dry bush or trash filled can would likely start a fire, so use caution.

Figure 2 shows the basic parts of a smoke bomb. A cardboard tube is plugged at both ends with what is called "fire clay," also known as bentonite. This is a powdered clay that is rammed into the tube and compressed into a hard, solid plug that is very resistant to burning. Fire clay is one of the most commonly used substances for plugging the ends of tubes used to make fireworks. Not only does the clay resist erosion from heat, it grips the tube wall very tightly when rammed, thus giving it the ability to hold up to high pressures when composition is burning in the tube. Fire clay can actually be found in the soil of many southern states, appearing as white lumps that are pliable when wet but crumbly when dry. Commercial fire clay which has already been ground into the powdered state is commonly available from most hobby firework chemical suppliers as well as pottery supply stores. Large quantities of bentonite are also used at metal foundries for use in making casting molds.

The composition which burns to produce the smoke is a mixture of potassium nitrate, sulfur and charcoal-- the same three ingredients used to make black gun powder. Smoke bomb composition differs from gun powder in that the sulfur content is very high and the charcoal content is very low, which produces a very slow burning pile of yellowish powder. Smoke bomb powder must burn very slowly in order for it to produce smoke, otherwise it will only shoot flame and sparks out the end of your tube.

Because the smoke bomb formula used here burns so slowly, it can often be difficult to ignite. If the fuse were run straight into the smoke bomb composition, it would usually have trouble getting it to ignite. To get around this problem, a small amount of "prime" is used to start the smoke bomb. Prime contains the same three ingredients as the smoke formula, but the formula is altered to give a faster burning and easier to ignite powder. The prime takes fire from the fuse, and then the smoke powder takes fire from the prime. As the name implies, a prime is the "primary" ignition point which in turn passes fire to a secondary substance which is more difficult to ignite.

The process of building a smoke bomb thus involves charging a strong paper tube with the following sequence: clay plug, prime, smoke composition and clay plug again. The last step is to drill a hole through the first clay plug and into the prime, which is where the fuse will be inserted.

Construction

The first step is to find a suitable tube for your smoke bomb. The dimensions of the tube, or casing as it is called, does not have to conform to any specific size. The longer the tube is, then the longer the smoke bomb will burn and thus the more smoke it will produce. Long burning smoke bombs will get quite hot and eventually burn through the side unless the casing is thick enough, so larger smoke bombs will need thicker walled tubes.

The casing used here was 3/4 inch inside diameter (I.D.) with a 1/8 inch thick case wall, making the outside diameter (O.D.) equal to 1 inch. The length was 2-1/2 inches, which will give a smoke duration of one and a half minutes.

The tubes used here were hand rolled from two 14" long by 7-1/2" wide strips of manila file folder paper, with an additional two turns of 30 pound kraft paper at the end to keep the case from unraveling. The basic procedure for rolling your own tubes can be found here. Since smoke bombs do not put much pressure on the tubes, you can also use dry-rolled paper or the cheaper commercial tubes made from recycled paper. However, the use of white glue when rolling your own tubes actually produces a tube that is slightly more fire resistant, so your smoke bomb can burn longer before burning through the side when using tubes made this way.

The white smoke formula used here is the Degn White. The three ingredients are weighed out on a scale one at a time, which will give you relative amounts that look like Figure 3. The best way to mix

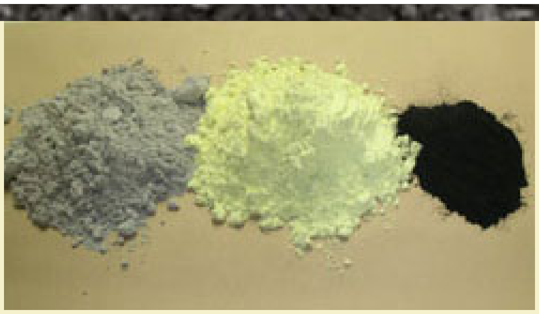
Figure 3: Weighed out ingredients prior to mixing.

Figure 4: Smoke composition after mixing.

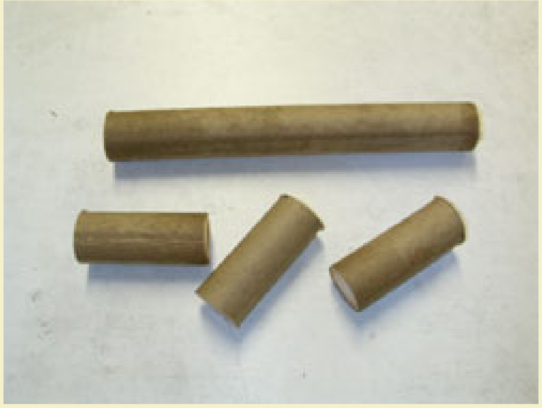
Figure 5: Cutting smaller tubes from a long one.

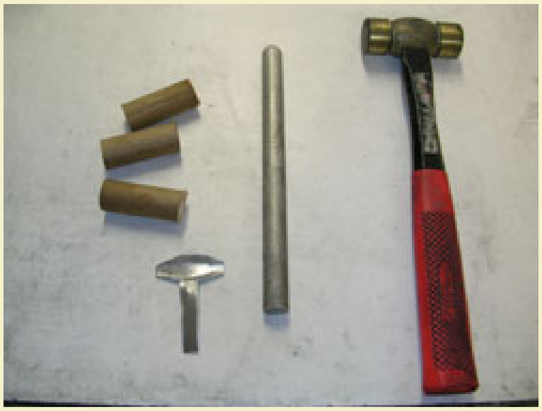

Figure 6: Tools required to charge the tubes.

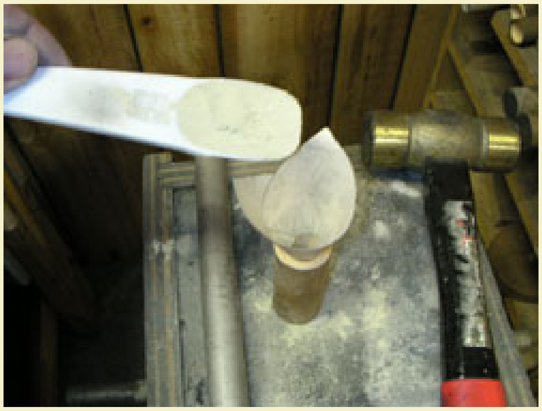

Figure 7: Loading 1/2 tablespoon of clay for the end plug.

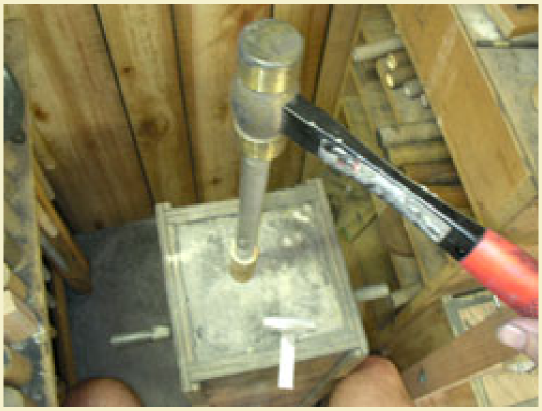

Figure 8: Ramming the clay plug.

these together is to push them through a screen three times, which will give you the finished composition seen in Figure 4. For more information about making your own screens, read here. The charcoal used in this formula can be very low grade stuff. Even ground up charcoal briquettes will work.

The basic tools for loading your smoke bomb are shown in Figure 6. These include a ramming rod equal to the I.D. of your tube, and a non-sparking mallet such as the brass one shown. Note that your ramming rod needs to have a flat, squared off end, especially when ramming the clay plug. If the rammer has rounded edges, then the plug will be concave on the inside and this will result in an extended period of smokeless flame projection before the smoke effect kicks in.

More...

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Smoke Bombs...

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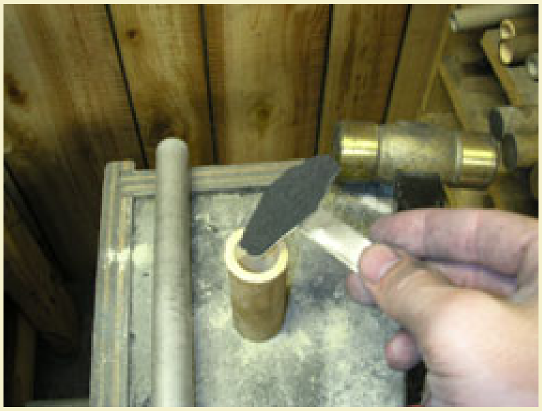
Figure 9: Loading a scoop of prime.

You will need to ram your smoke bombs on a solid surface, such as a concrete block or a thick block of wood such as a log set on end. Any vibration on your work surface will result in less density in the resulting smoke charge.

Begin by loading one half table spoon of fire clay into your case, using a funnel to help guide the powder as seen in Figure 7. This should be rammed in with seven or eight solid blows from your mallet (see Figure 8).

After ramming the plug, dump in a small increment of prime as seen in Figure 9. I use a small scoop made from a scrap of aluminum flashing to allow dumping the powder in without using a funnel. The prime formula can be "green mix," which is an unprocessed mixture of black powder that is mixed the same way as described for the smoke bomb powder. You can also use any black powder based rocket fuel or fountain mix you have laying around for the prime.

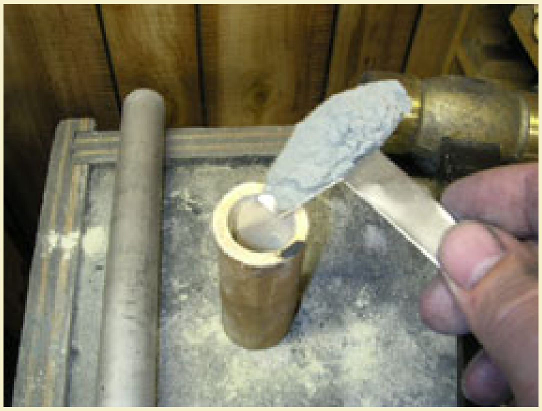
Figure 10: Loading a scoop of smoke composition.

Before ramming the prime, add an increment of smoke bomb composition on top of it. By ramming both types of composition together in loose form, you will get a better fire transfer between the barrier where the two meet.

Continue adding and ramming smoke bomb composition in about 1/2 tablespoon increments until the case is filled to within 1/4" from the top. Figure 11 shows how high you want to ram the smoke composition before stopping. The increment size determines how dense the composition will be, with smaller increments producing more dense and thus longer lasting smoke bombs.

Finish loading the case by ramming in a final plug of fire clay. Fill the remaining void to the top with clay and ram the plug with about 8 blows from the mallet.

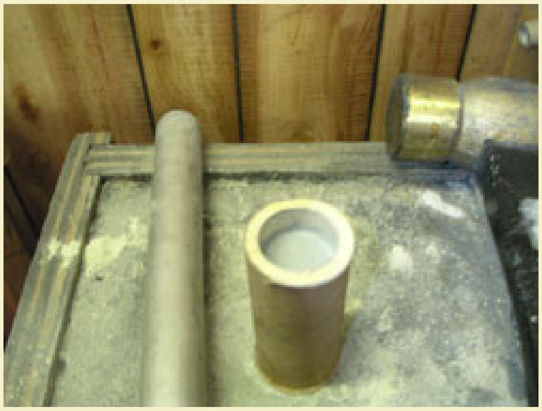
Figure 11: Stopping point for smoke composition before loading clay plug.

Next you will need to drill the exhaust hole in the plug on the primed end. This hole should be 1/8" in diameter, which can be drilled on a drill press with the speed set to the lowest RPM available. Black powder and smoke composition are not very sensitive to friction, so it can be drilled without worrying about igniting the composition. You still want to avoid high RPMs that could heat up the material and push the limits of friction sensitivity. The hole can also be drilled with a hand held power drill, but a cordless screwdriver is preferable for its inherently lower RPMs than a power drill.

Smoke bombs are typically fused with a stick of waterproof Visco type safety fuse measuring roughly 1-1/2" long. Black match could also be used if you have some small enough to fit into the 1/8" diameter hole.

Even though your fuse may fit snugly into the vent hole, it is a good idea to secure it in place using what is called "nosing paper" around the end of the casing. The "nosing" is simply two turns of a thin weight paper that is glued around the end of the case so that it overhangs by about 1-1/2 inches. The 30 lb kraft nosing paper seen in Figure 13 is 7 inches long by 3 inches wide. The paper that overhangs the end of the case is then gathered up around the fuse and secured with a clove hitch knot. For instructions on tying a clove hitch, refer here.

The 2-1/2 inch long smoke bombs will burn for 1-1/2 minutes, which is long enough to produce quite a bit of smoke. I have tested the hand rolled manila cases up to four inches in length without getting any burn through, although the case does get hot enough to burn things so be careful where you place it.

Breathing a small amount of the smoke won't hurt you, but too much of it will likely make you feel ill so make sure you don't fire these in such a way that the wind can blow the smoke into your home and stink it up!

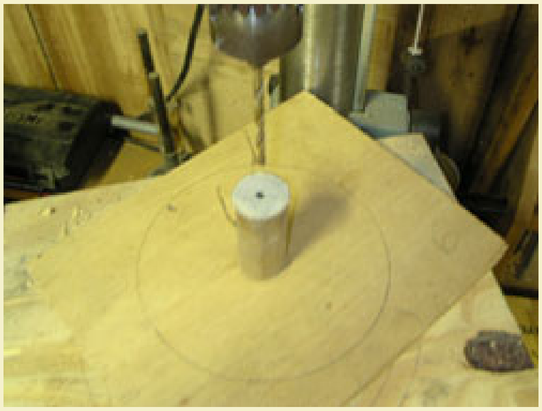
Figure 12: Drilling the 1/8" vent hole.

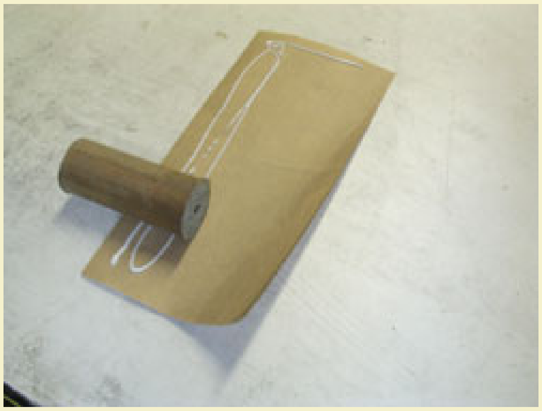
Figure 13: Applying the nosing paper.

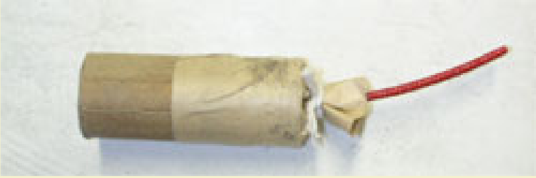
Figure 14: Smoke bomb ready to use.

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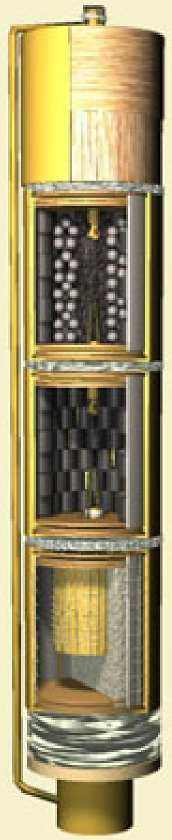
Volume 2, Issue 9

Build This...

6" 3-Break Maltese Shell w/ Bottom Shot: Part 1



Summary:
The Maltese are known the world over for their large multi-break shells, which they manufacture year around for display in several annual festivals. Construction of these large shells varies considerably from the traditional Italian methods described in most literature.

This month begins the first of a two part series that gives detailed information for constructing a typical three break Maltese shell. While this six inch shell is not considered large by Maltese standards, it is a good starting point for advanced shell builders to try their hand at Maltese style shells. The finished shell will weigh about 20 lbs and stand about 3 ft tall, making this a respectable shell for competition or any special occasion.

September, 2002 Issue

Build This:
6" 3-Break Maltese Shell

Technique:
Making Cut Stars

Tool Tip:
Star Cutting Tools

Class C Corner:
Beef Cake!

Article Update:
Assembly-line ball shell pasting.

NEW! Chemical Price Chart

NEW! Round Shell Star Counter

Perquisite Reading: Maltese Multi-break Shells

Materials:

- (8) 6" disk w/5/8" hole
- (6) 6" disk w/1-1/8" hole
- (2) 6" solid disk
- (2) 4" disk w/5/8" hole
- (2) 4" solid disk
- (4) 9" wide x 36" long strips poster board
- (2) 5" wide x 23" long strips poster board
- (4) 9-1/2" wide x 36" long 60 lb kraft
- (1) 8" wide x 34-1/2" long 60 lb kraft
- (8) 3-1/2" wide x 14-1/2" long manila folder strips
- (4) 3-1/2" wide x 6" long 30-lb kraft
- (1) 3-1/2" wide x 24" long chipboard
- (1) quart water mixed w/30g gum arabic

Tools:

- 4" case former
- 6" case former
- 1/4" dia. dowel or metal rod
- Drill press
- 5/8" spade bit or center punch
- 1-1/8" spade bit or center punch
- Thin, sharp knife with 6" blade or longer
- 4-spool/cone twine dispenser
- 1" eyelet
- 3" paint brush

- (1) half quart of 50/50 glue/water
- (1) half quart of 50/50 glue/wheat paste
- (3) cups wheat paste
- (300) grams flash powder

Unmeasured Materials:
White glue, cotton twine, sand, black match

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6" 3-Break Maltese Shell, Part I...

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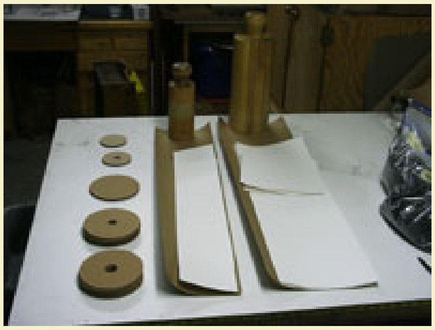

Figure 1: Punched disks, 60lb kraft strips and poster board strips for making four 6" cans and one 4" can.

Introduction:

The construction of Maltese shells has evolved over the years to make use of available materials while also keeping costs down. Anyone who has ever built large shells knows how much material they can consume as compared to smaller shells. The majority of shells fired at Maltese fireworks festivals are large multi-breaks, many of them eight and even ten inches in diameter!

The casings for Maltese shells are constructed quite differently than those of Italian style shells. Because their kraft paper comes from a low grade of recycled kraft used to make the paper bags concrete is shipped in, their shells are designed such that the neither the quality or the grain direction of the kraft paper matters. Instead, poster board and paste is used to reinforce the shell casing, pumped stars are used to provide horizontal integrity and a full blanket of spiking twine gives the desired burst containment.

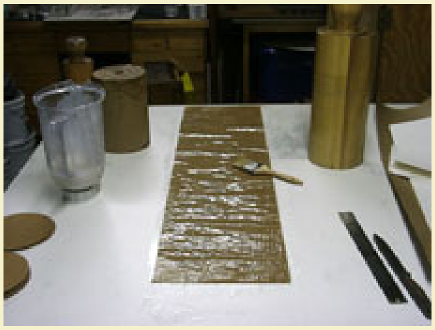

Figure 2: Paste is painted onto one side of 9.5" x 36" 60lb recycled kraft. Grain direction does not matter.

Making the Cans:

Regardless of what size shell is being constructed, the cans for each break are constructed from two turns of 60 lb recycled kraft pasted together with two turns of a cardboard paper that is the thickness of poster board paper. Typical white poster board paper found in art supply stores works well and will be used for the shell described here.

Before you roll the cans you must first prepare the disks that will be used. The following list shows the hole size and count of the disks required for this shell:

5-1/2" dia. Disks:

(2) solid (bottom of last break)
(6) with 1-1/8" dia hole (bottom of color breaks)
(8) with 5/8" dia hole (top of all breaks)

3-1/2" dia Disks

(2) solid (bottom of salute)
(2) with 5/8" hole (top of salute)

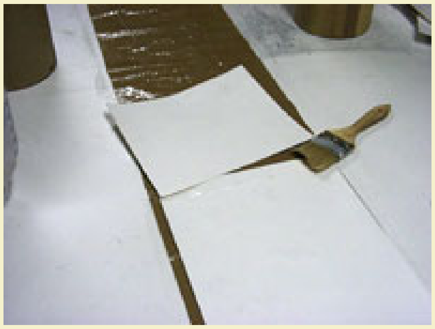

Figure 3: If a 36" strip of poster board is not possible, connect shorter pieces by overlapping.

The holes specified here are for use with a 5/8" O.D. spolette tube. If your spolettes are a different size, then you will have to adjust the hole sizes. Holes can be punched using a hammer and die set, or they can be drilled out using a drill press.

Since the cans are pasted and must dry, all cans for the shells to be built are rolled at the same time. Cans are constructed with the bottom disks in place for the color breaks, while the last bottom shot break is constructed with the top disks in place. Thus, you will make three cans using the 1-1/8" hole disks, then one can using the 5/8" hole disks.

Figure 1 shows all components ready for making the cans. The following strips of paper should be prepared:

60 lb recycled kraft:
(4) 9-1/2" wide x 36" long
(1) 8" wide x 34-1/2" long

Poster Board:
(4) 9" wide x 36" long (splice using 28-1/2" + 7-1/2")
(2) 5" wide x 23" long

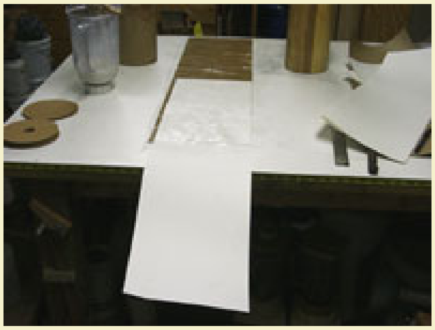
Figure 4: Poster board overhangs the kraft half its length. Paste is applied to the poster board only where it overlaps the kraft.

Begin by laying out the 36" strip of kraft and applying paste to one side using a paint brush. There is no need to paste the other side or break the paper, just apply paste on one side only as seen in Figure 2.

Take the sheet of poster board (the longer sheet if two pieces are required) overlap the kraft paper such that 18" hangs over the end of the kraft, as seen in Figure 4. Apply paste only to the part of the poster board that is overlapping the kraft. If you have a second smaller piece required to get the full 36" length, overlap the first sheet by about 1/2" as shown in Figure 3. Apply paste to this smaller piece of poster board as well.

More...

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6" 3-Break Maltese Shell, Part I...

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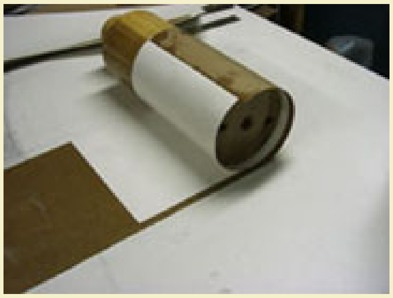
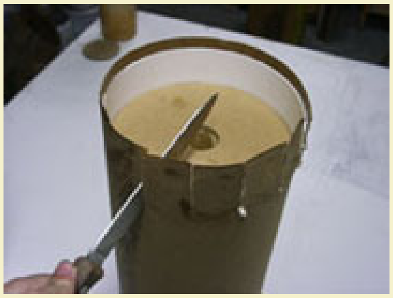
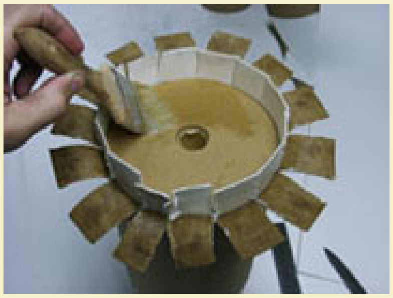
The following sequence of steps shows how the case is constructed. The knife used in Step 2 should be very sharp and as thin as possible. The tabs should be cut quickly before the paste has a chance to seep into the poster board, which will make cutting difficult. Remember that you will be making three cans using the 1-1/8" hole disks and one can using the 5/8" hole disks.



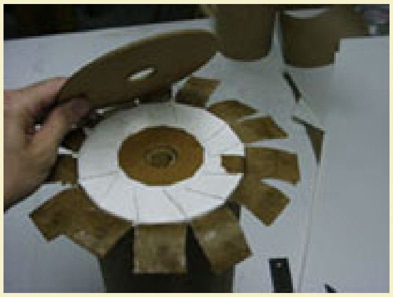
Step 1: The poster board and kraft are rolled up onto a 5-1/2" dia case former. The edge where the kraft extends beyond the poster board should be on the flat side of the former.



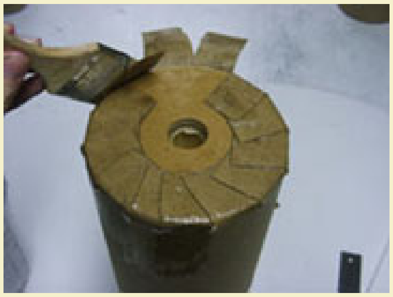
Step 2: Insert a disk with a 1-1/8" dia. hole and leave about 1.5" of poster board extended. Quickly cut tabs around the edges using a thin, sharp knife.



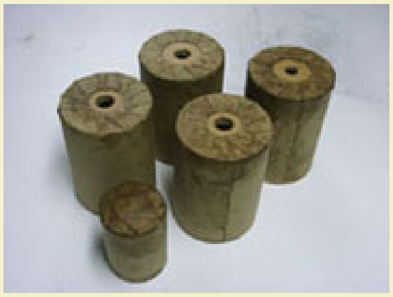
Step 3: Separate the kraft paper from the poster board, then coat the end disk and tabs with paste.



Step 4: Fold the poster board tabs down onto the disk, then place another disk with the same sized hole on top.



Step 5: The kraft paper tabs are now pasted down over the second disk.



Step 6: Build three cans with the 1-1/8" holes, then a fourth can with the smaller spolette sized hole. Also shown is the 4" salute can.

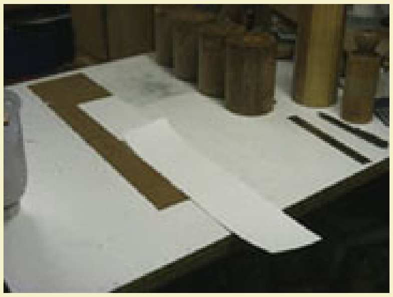


Figure 5: The salute can gets four turns of poster board.

Making the Salute Can:

The salute can will be filled with flash and located inside a full sized break, surrounded by sand. Because burst symmetry is not an issue and this casing will not subjected to the full lift force and gas pressures, it is not constructed the same way as the main breaks.

Since the salute does need good confinement for a loud report, it is made using four turns of poster board instead of two. The case is made using two strips that will go around the former twice, which are pasted and stacked as seen in Figure 5. Again, one full turn hangs beyond the kraft, which does not get pasted on top so that the former does not get stuck to the case. The two poster board strips are also offset from each other so that the seems fall in different places.

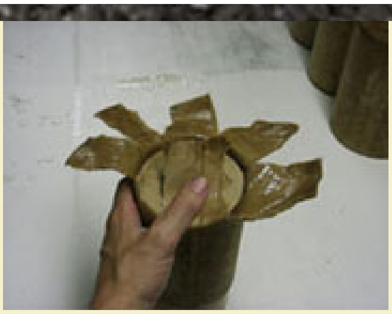


Figure 6: A single solid disk is pleated over using only the kraft paper.

Because the poster board tabs are not required to be folded over the end disk, the kraft paper is a bit wider than the poster board. The paper is rolled up with the kraft overhanging the end of the former, then a solid disk is put in place. The overhanging paper is torn and folded down over the disk to secure it.

All cans are now set aside to dry for a few days. Accelerated drying via the use of a fan or dry-box can be used to speed up the process.

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Making the Spolettes:

The type of tube used to make spolettes is very important. The inside diameter should be kept small, about 1/4", so that there is less surface area for the internal shell pressure to act on. The tube walls must be thick and made from strong paper in order to prevent the tube from splitting during loading. Because a lot of pressure will be acting on the powder charge when each break bursts, the powder must be rammed as hard as possible to lock it in place and prevent blow-through. Blow through occurs when the burst pressure of one break blows the spolette charge out the end of the tube and sets off the next break simultaneously, ruining the shell.

Tubes sold as "spolette tubes" by most hobby suppliers are inadequate for the job. While it is possible to find good quality spolette tubes, they can be expensive and often must be purchased in bulk quantities. For this project we will roll our own spolette tubes in a way similar to how the Maltese also make them.

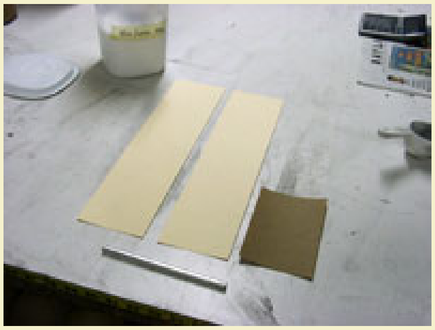

Figure 7: Two 14.5" strips of file folder paper and a piece of 30lb kraft for rolling spolettes.

An ideal paper for making spolettes is manila file folder paper. Using the legal size folders, which are 14.5" wide, cut two 3.5" wide strips for each spolette you will make (eight strips altogether). You will also need a 6" long strip of 30lb kraft that is also 3.5" wide. Figure 7 shows the paper and a 1/4" dia. aluminum rod used to roll the tube on.

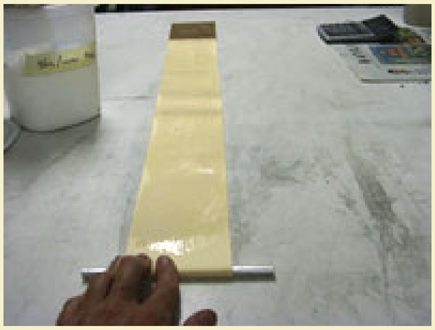

Figure 8: Strips are laid end to end and painted with a 50/50 mixture of white glue and water.

Using a mixture of 50/50 white glue and water, paint the surface of the kraft strip first, then overlay a manila strip by 1/4" and fully coat it. Overlap the second manila strip by 1/4" and coat all of it except the last few inches. Begin rolling the tube from the dry end, as seen in Figure 8. If your paper is aligned straight and your rolling rod was perpendicular to the paper, you should get tubes that look like Figure 9. These should be 5/8" O.D. and fit snugly into the hole punched in your top disks. These tubes must be allowed to fully dry before loading.

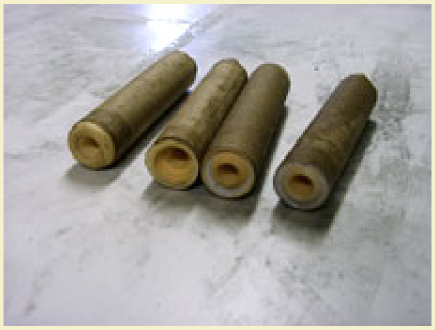

Figure 9: Finished spolette tubes ready for drying.

The spolettes are rammed very hard with meal in several increments as if building a rocket, only there is no nozzle and the powder runs flush with one end of the tube. If your tubes came out concaved on one side, cut off a small length or sand them down to get the end level on the powder side. The other end does not need to be flush cut.

The burn time for these spolettes needs to be about 2 seconds each, and no more than that. Depending on how fast your powder is and how hard you ram it, this will be a charge of between 5/8" and 7/8". You will have to do timed trials with whatever meal you are using to determine the correct powder charge.

The Maltese do not drill back their powder cores, or even use the tapered rammer for the last increment (see spolette article). However, I find it easier to simply ram in three 1/4" teaspoon increments and then use a drill press with a depth-stop setting to drill through the excess comp to form a small hole that stops at the correct height of the powder core (see Figure 10). This not only achieves consistent and accurate timing across all spolettes, but also improves ignition on the passfire side. The more powder rammed into a spolette, the harder it is for burst pressure to blow through it. Thus, the drill-back method also decreases blow-through risk.

Once all the spolettes are loaded, two turns of 30 lb kraft are rolled around them so that about an inch of paper overhangs each end, as seen in Figure 11. A strip of paste is brushed down the center from end to end so that no gas can pass between the spolette tube and the paper.

Three sticks of black match are tied into the nosing paper on the passfire end, while the paper on the other end is twisted around the exposed powder core as a protective covering.

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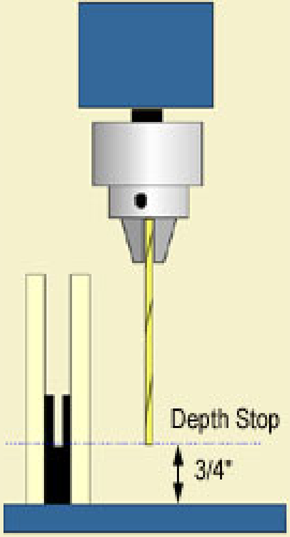

Figure 10: Using a drill press to drill back spolettes.

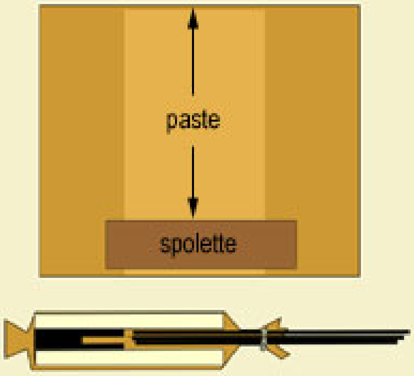

Figure 11: Rolling on the nosing paper and tied in black match.

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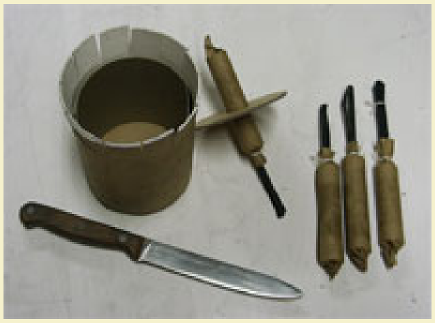


Figure 11: Salute can with chipboard liner and sliced tabs around edges.

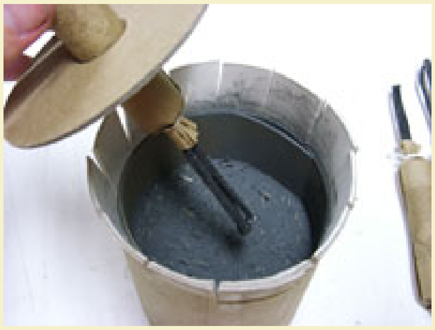


Figure 12: 300 grams of flash mixed with rice hulls.

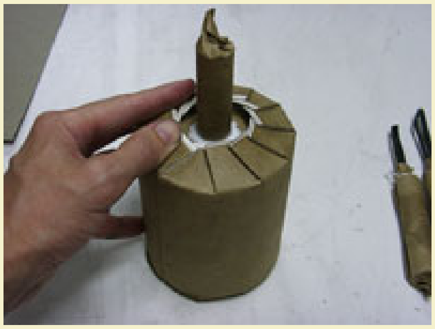


Figure 13: Folding tabs down over disk.

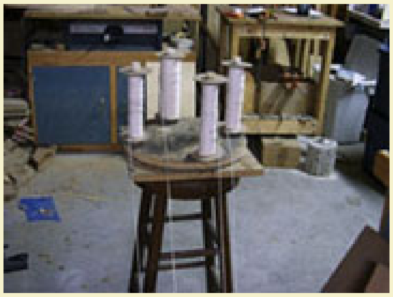
Making the "Bomba":
The bottom shots for larger Maltese shells typically contain a smaller salute nested inside a larger shell casing. When constructing the inner "bomba" salute, the Maltese use a mixture of chlorate flash and sawdust to fill the can solid up to about 1-1/4" from the top, then they place the disk directly on top of the flash. The tabs are then cut after the disk is in place.

Since I am not comfortable mixing finely powdered aluminum with chlorates, I opt for the standard 7:3 perchlorate flash. This is diluted with rice hulls by about 1/3 in volume and the case is only filled 2/3 full. This probably does not produce as loud a report as the traditional Maltese salutes, but it is safer and uses less flash to produce.

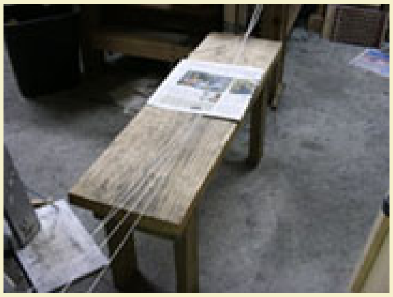
Because I do not fill the can solid with flash, a few turns of chipboard are used to line the inside wall so that the end disk will be supported when closing the shell. I also prefer to cut the tabs before loading the flash, since I don't like the idea of any friction generating activity in the presence of flash. Insert the chipboard, put a disk over it and then cut your tabs using a sharp knife as seen in Figure 11.

Figure 12 shows the loaded case with the fused end disk being put in place. The spolette is not glued to the end disk yet, so it can slide up and down as necessary. Once in place, glue is applied around the spolette and the tabs are folded down as seen in Figure 13. A second disk will be placed over each end prior to spiking.

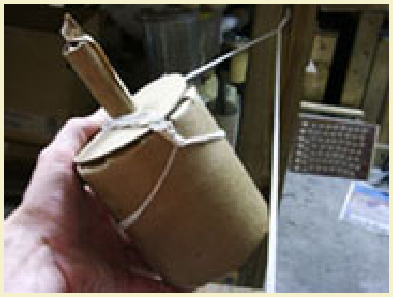
Steps 1-6 below show the procedure for spiking the salute. Spiking is done with four parallel strands of strong cotton twine. The tensioning mechanism is a simple yet clever technique whereby the worker actually sits on the string, using his weight to generate friction. The string passes through an eyelet in front of the worker, and may be crossed over several times to adjust the amount of force required to pull the string through the eyelet. This way the shell can be quickly wound by pulling the twine around it without having to walk or stop to unspool a spiking horse.



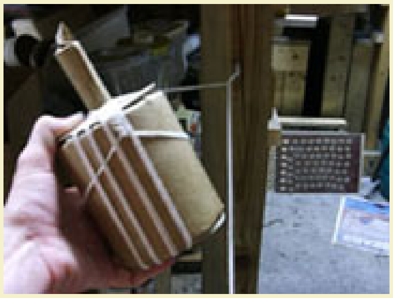
Step 1: Four spools or cones of cotton twine are placed behind the worker.



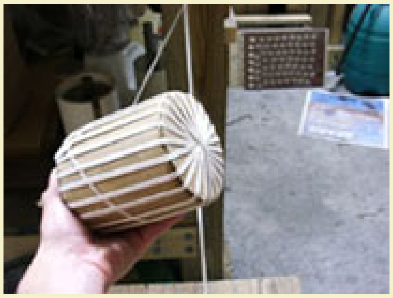
Step 2: Twine runs between two sheets of newspaper, which the worker sits on, then loops through an eyelet in front.



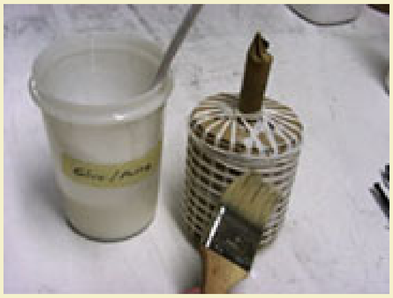
Step 3: Spiking begins by tying off around the shell itself, rather than the spolette.



Step 4: Vertical spiking is spaced at about 1/4" rather than counting any specific number of verticals.



Step 5: When the verticals are complete, the twine is run down the side to the bottom and spiked in the other direction. This horizontal spiking is also spaced at 1/4".



Step 6: Complete spiking by tying off around the shell. The twine is now completely coated with a mixture of 50/50 white glue and paste.

After the spiked shell has been thoroughly soaked with paste, it is placed on a screen to dry. When fully dried, two turns of 30 lb kraft are pasted over the shell to seal it.

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Assembling the Bottom Shot:
Rather than use the thick walled salute cores, which are used for both containment and providing vertical integrity in the bottom shots of Italian style shells, the Maltese reinforce their bottom shots by placing the salute inside a larger can and surrounding it with sand. The sand provides a non-compressible medium to withstand the lift forces without compressing and splitting the bottom break. This method is much easier and less expensive than trying to purchase or hand-roll a very thick walled tube from cardboard, which must be able to withstand the high compression forces exerted on the bottom break during lift.

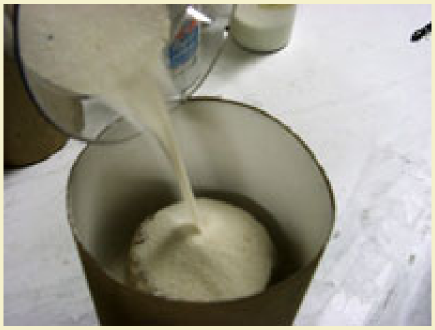

Figure 14: The 4" salute is inverted into the 6" can with the 5/8" hole, then filled around with sand..

Naturally the sand will add considerable weight to the shell, which is actually thought to help prevent the shell from tumbling in the air after leaving the mortar. The Maltese shell builders will sometimes cut the sand with a small percentage of sawdust to reduce the weight. When using sand mixed with sawdust, it becomes even more important to ram the sand down with a stick while loading.

The bottom shot can is the one that has the smaller 5/8" hole, which should fit snugly around the spolette of the salute. Insert the salute inside the can and push it as far as it will go. You will need at least 1.5" of spolette sticking out the top of the can, so you may have to enlarge the hole if the salute will not fit far enough down inside the can.

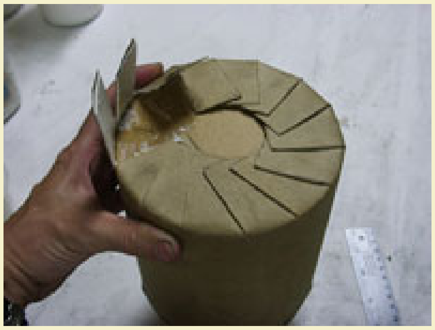

Figure 15: A solid disk is placed over the sand, then tabs are cut and folded.

Sand is now poured around the salute as seen in Figure 14. Pour in a few inches of sand, then tamp it down or settle it into the can by bumping it up and down. The sand should fill above the salute to within a few inches of the top of the can, then leveled off. A solid disk is placed directly on the sand, then tabs are cut using a knife as before. The tabs are folded down as in Figure 15. Gluing the tabs is optional, since another disk will be placed on top and held down by the spiking twine.

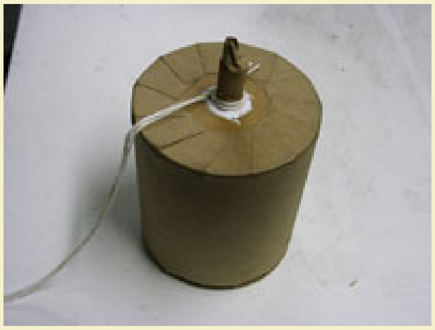

Figure 16: A second solid disk is placed on the bottom, then glue is applied around the spolette prior to spiking.

Turn the shell upright and apply liberal amounts of glue around the spolette. Four strands of cotton spiking twine are again used to spike the shell in the same way the inner salute was spiked. In Figure 16 I have tied off to the spolette instead of around the can, which I find to be a more logical thing to do because it helps seal around the spolette seam while also aligning the string in the direction required for vertical spiking.

When the vertical spiking has been applied to roughly half the shell, it is wrapped a few turns around the spolette before continuing the rest of the way around the shell. This helps keep the tension from slipping.

The spiked shell should look like Figure 17 when finished. The string should be coated with paste prior to wrapping the shell with two turns of 30 lb kraft pasted on one side only. Since all breaks will get two turns of pasted kraft for fireproofing, the bottom shot can be put aside and paste wrapped at the same time as the other three breaks after they are loaded and spiked.

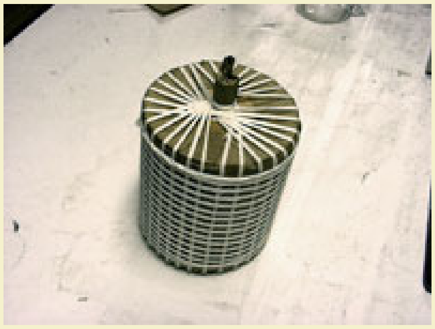

Figure 17: The finished bottom shot is spiked just like the inner salute was.

Part II

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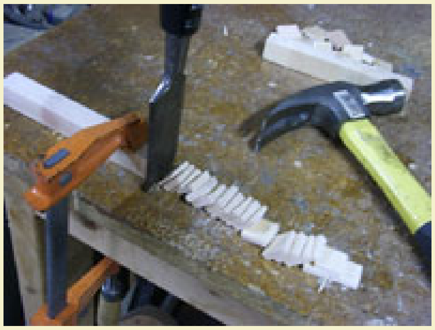

Figure 18: Cutting wooden wedges using a hammer and chisel.

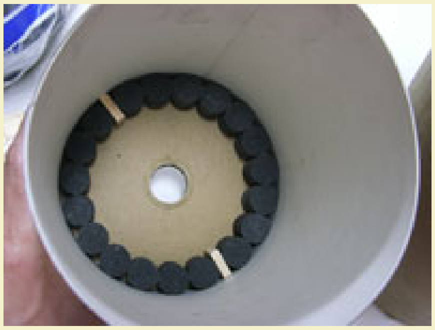

Figure 19: Wedges used to lock each row of stars tightly in place.

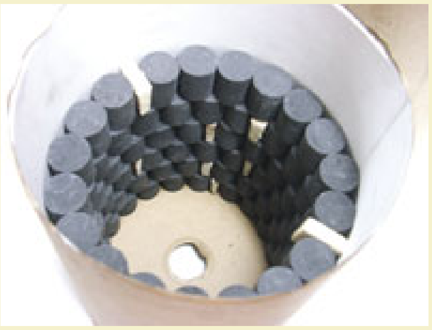

Figure 20: Six rows of nineteen stars per break.

Loading the Breaks:

The color breaks of Maltese shells use pumped comets stacked in rings to insure vertical shell integrity, which helps prevent the shell from rupturing during lift. The comet formulas often contain dextrin, but gum arabic is also added to the binding solution to make the stars extremely hard so that they don't shatter when the shell breaks. About 30g of gum arabic per quart of water is used, which will sour upon extended storage but still remains usable nonetheless.

Loading the breaks requires lots of 3/4" comets and some wooden wedges. Rather than tamp sawdust around each comet as the Italians do, the Maltese builders wedge pieces of wood of various widths until the ring is locked in place. The wooden wedges must be cut from a piece of pine where the grain runs parallel to the thickness of the board. This means that the board has to come from the center of the tree, which is where the wider dimensions of lumber are cut from. It is easy to find a 1x10 with grain running in the proper direction, but not 1x4s or 1x5s. Figure 16 shows how a 3/4" strip cut from the edge of a 1x10 is clamped to the table with the end grain facing upwards. A chisel is then used to hammer out wedges of various random widths ranging from 1/4" to 1/8". The taper on each wedge should be minimal.

Since potassium chlorate is much cheaper in Malta than potassium perchlorate, it is used almost exclusively for both stars and flash powder. The chlorate stars are also preferred for their higher light output and shorter burn time. While US manufacturers strictly avoid allowing chlorate compounds to come in contact with sulfur containing compounds, the Maltese slurry prime their comets and stars using a mixture of black powder and gum arabic. While they have done this for many years with minimal accidents, there is still the hazard of increased sensitivity when loading shells with meal primed chlorate comets. Great care must be taken not to force the comets too hard when loading the rings, and this practice is definitely not recommended for the novice shell builder.

One trick the Maltese use to avoid having to force the comets when building the rings is to load the shell while the cans are still slightly damp after having been rolled. The comets are wedged in snugly, but not forced at all. Then as the can fully dries, it will shrink up around the comets and secure them more firmly.

The comets used for all three breaks in the shell being built in this article are Lancaster's Yellow Glitter, bound with 10% of the above mentioned water/gum arabic solution. These comets must be pressed very hard such that you can not break them or even chip pieces off of them after they dry. For more information on making pumped comets, read this article. These comets really need to be primed with meal powder to insure ignition, although they are not primed in this picture. Priming comets is best done using a star roller fitted with temporary lift bars, made by taping dowel rods or lengths of rope to the sides of the roller drum using duct tape.

The comets used here are 3/4" diameter and 7/8" tall. It is important that every comet is the same height. Each ring will contain 19 unprimed comets, or 18 primed comets. Each break gets six rings, thus will need to pump either 324 or 342 comets, depending on if you are using a composition that needs to be primed or not. Be sure to pump a few extra for dryness testing and burn tests.

Place all 18 or 19 comets in each ring and then find wedges that fit the remaining gaps and force them in place. The last wedge should require a bit of force to insert, otherwise the ring is too lose. Comets for each successive ring should be placed between the comets of the previous ring, so that the result looks like a brick wall. Figure 16 shows one fully loaded break.

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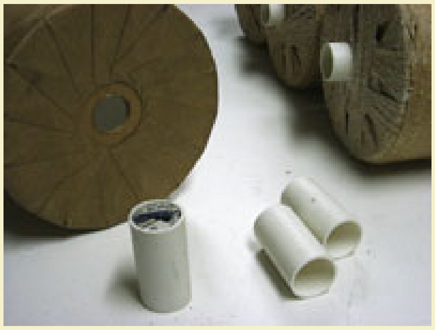

Figure 21: Plugging bottom holes with PVC plugs.

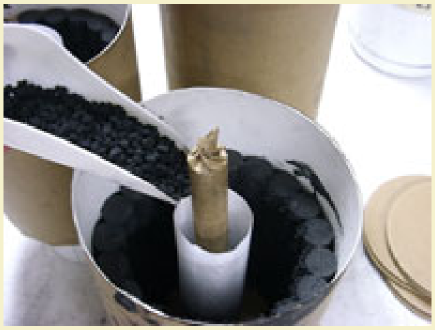

Figure 22: Filling tissue paper burst bag with 1/4" rough powder while spolette is held in place.

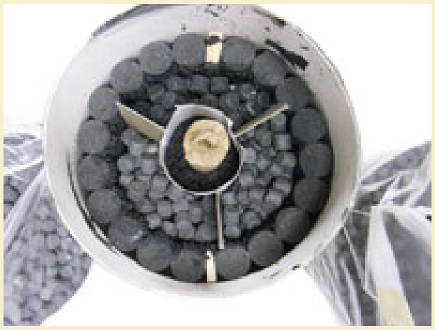

Figure 23: Temporary chipboard dividers used to section off three color compartments.

Before the burst core can be loaded, the hole at the bottom of the case must be plugged. Small segments of PVC with paper stuffed into one end are used for this. Since paste does not adhere to PVC, the plugs can easily be removed once the case is completed. If you can not find PVC that fits the hole tightly enough so that it doesn't fall out, wrap a few turns of newspaper around the ends until it fits tightly. This plug must remain in place from this point until the breaks are ready to be assembled.

The inner effect of all three breaks for this shell will be a triple color compartment design. The traditional method for doing this is to take a thin, hollow center tube and tape three cardboard fins that create three equally spaced compartments when inserted into the shell. The center tube is filled with burst, then each compartment is filled with a different color star. Finally the tube is carefully pulled out, taking the cardboard fins with it.

The method I use here is slightly different, due to the fact that thin metal tubes of the proper diameter are hard to find. Using PVC or paper tubes tends to present a jamming problem when you attempt to remove them, cause by stars biting into the softer material. I find it much easier to roll a burst bag using two turns of tissue around a 1-1/2" former, gluing the edge and inserting it into the center of the shell. The former is removed, leaving a thin bag to hold the burst charge.

Figure 22 shows the burst bag being filled with 1/4" rough powder. This rough powder should be made from home made meal and a good quality charcoal such as willow, paulownia or spruce. It should pass a 1/4" mesh hardware cloth and sit on top of a 1/8" hardware cloth. This is your break charge. No black powder, no flash bags, no whistle mix- just rough powder.

The spolette is centered down in the burst bag as the burst charge is poured around it. About two inches of the spolette should stick out beyond the top of the comets. This method avoids the problem of trying to push the spolette into a charged burst core when building shells from the bottom up.

Figure 23 shows the inner core of color stars filling three separate compartments. One inch wide strips of chipboard are loosely inserted to form the compartment walls. The appropriate bag of colored stars are located next to each compartment when loading the stars, which helps prevent loading the wrong color into a compartment. The 1/4" rough powder is mixed in with the stars in alternating layers. First a handful of stars is placed in each compartment, then enough rough powder to cover them, then another handful of stars etc. When the top is reached, a final layer of rough powder is used to level off the shell. The rough powder helps lock the stars in place as well as bursting the shell.

Once the shell is bumped up and down to settle the contents and leveled off

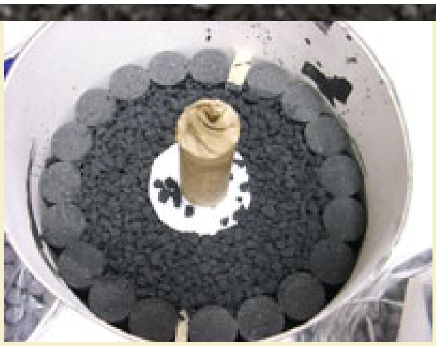

Figure 24: Rough powder used to fill in level with top of comet rings.

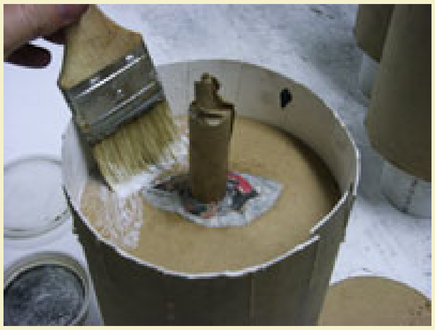

Figure 25: Pasted newspaper sealed around spolette. Glue and fold tabs as shown previously.

with more rough powder, a disk is placed over the spolette and worked down until it rests on the shell contents. Because the Maltese use chlorate stars, they add a ring of crumpled newspaper above the comets before closing the shell. Since the disk will be a tight fit, hammering with a wooden stick is often necessary to seat the disk firmly. The paper padding is a shock absorbing barrier between the chlorate stars and the impact of pounding the disk. Because we are not using chlorate stars here, the paper was omitted.

As with the bottom shot, pasted newspaper is used to seal around the spolette and the overhanging can walls are sliced into tabs and glued down. A second disk is then glued on top of the folded tabs.

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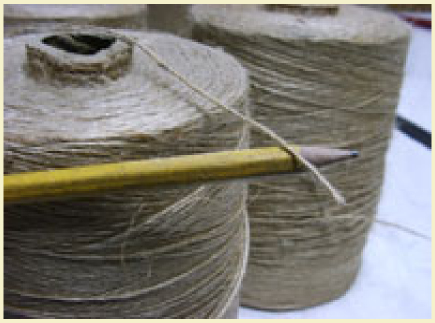


Figure 26: A special single ply jute twine used to spike color breaks.

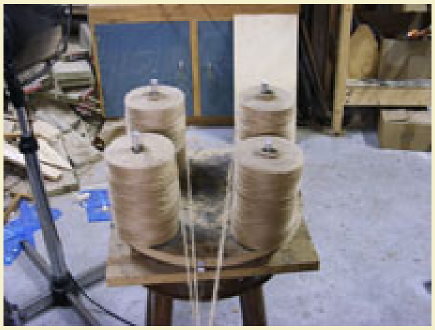


Figure 27: Four spools are used to apply four strands at a time.

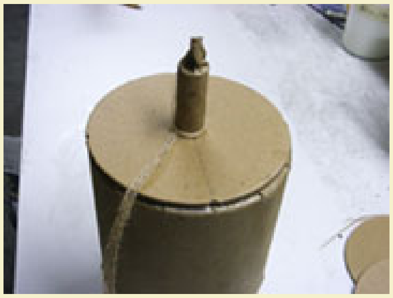


Figure 28: Four strands are passed through spiking eyelet and tied off to spolette.

Spiking the Breaks:

Up until this point, life has been good. The cans were quickly made with no tedious pleating of paper. The breaks were loaded without going through a fortune in black powder. Pumping the comets was a drag, but other than that it has been pretty easy. Now comes the hard part.

Because these thin walled cans do not provide much containment, you have to spike the living daylights out of them. There is no counting of verticals such as when building Italian style shells. You simply spike a continuous wrap of twine until you can't see the shell anymore!

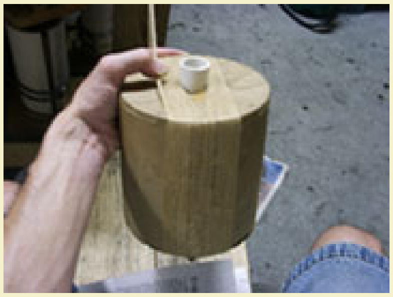
The type of twine used to spike the color breaks is very important. Cotton can not be used, nor any other type of twine that stretches. Flax is too strong, and most jute is too thick. A special single ply jute twine is required, as seen in Figure 26. This twine is quite thin, about 1/16" in diameter, and breaks with little effort when pulled. The very same twine the Maltese use on their shells is available in huge rolls from pyrosupplies.com, which is the only supplier I know of that carries it.

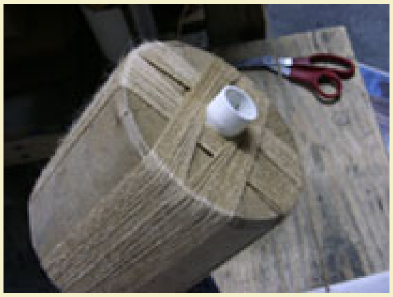
To keep the twine from breaking when spiking, as well as to make the process go faster, it is applied four strands at a time. Figure 27 shows four spools that sit on a dispenser behind the worker. The setup is the same one used to spike the bottom shot, where the twine runs between sheets of newspaper that the worker sits on, through an eyelet in front of the worker, and to the shell being spiked.

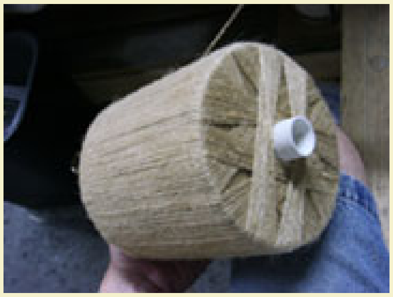
Steps 1 through 6 show the procedure below. Note that when starting each vertical band of twine, start from the center and progress away from the center. Once one side is complete, cross back to the center and spike from the other side as you progress away from the center again. The vertical spiking consists of four thick bands of parallel spiking that completely cover the shell.

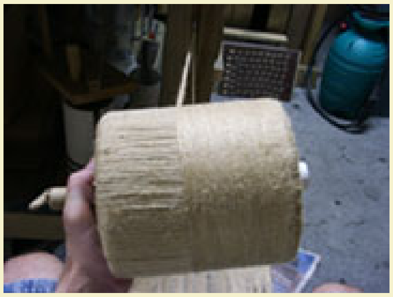
The Maltese actually apply the vertical spiking by holding the shell with one hand and pulling the twine around it with the other. I find this method more difficult and tiring, preferring to use the Maltese salute spiking setup instead.

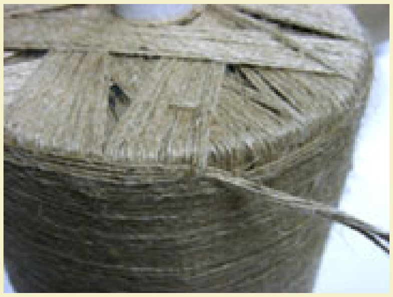
When applying the horizontal spiking, you may consider the use of the Maltese shell rolling tool described here. The roller supports the weight of the shell while the operator uses one hand to rotate the shell and the other hand to guide the twine.

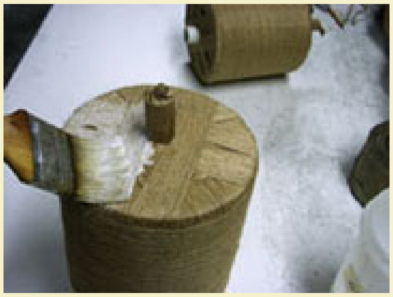

Step 1: Vertically wrap solid, wide bands of twine on both sides of center.


Step 2: Making another wide band perpendicular to the first.


Step 3: Fill in remaining spaces with another set of intersecting bands of continuous spiking.


Step 4: Horizontal spiking is also done in one continuous twine wrap.


Step 5: Slip last horizontal wrap under a few plies of twine from atop the shell and glue the lose end.


Step 6: Applying glue/paste solution to top and bottom of spiked shell.

If you are using a weaker grade of twine, you will invariably have a strand of twine break on you at least once during this process. This usually occurs at the eyelet and is caused from snared threads or thin spots in the twine. The strand must be repaired, which is often an aggravating task.

When spiking is complete, the twine at both ends of the shell are saturated with a mixture of white glue and paste (50/50). No glue is applied to the sides of the shell, only the ends.

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Pasting in the Breaks:

Once the glue fully dries on the ends of the three breaks, they are ready to be pasted in. Begin by slathering a thick paste slurry over all the twine, including the top and bottom. The jute twine will quickly soak up the paste, making it much stronger than if the paste was not applied.

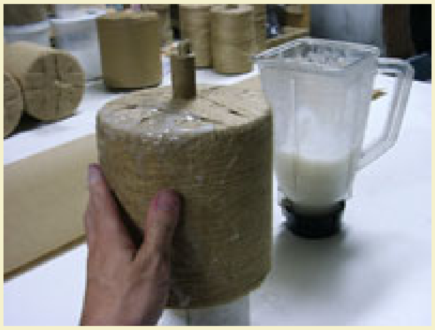

Figure 29: Coating the twine with paste.

After coating the twine with paste, prepare a sheet of 30lb recycled kraft paper that is 36" long and wide enough to reach from the base of the PVC pipe to just a little past the base of the spolette. Paste one side of the kraft only, then roll up the shell. The shell should be positioned on the paper so that the bottom overlap just reaches the base of the PVC plug, while the other end is able to wrap around the base of the spolette slightly.

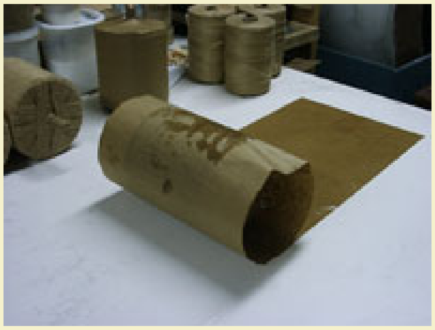

Figure 30: Rolling on two turns of pasted 30lb kraft.

The paste wrap is torn and folded over the ends in the traditional manner, as seen in Figure 31. This thin recycled kraft will lay down really easily and conform tightly to the shape of the shell. Rub paste all over the outside of the wrap so that there are no dry spots. The finished breaks should look like Figure 32.

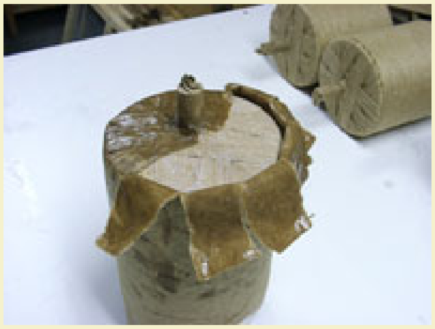

Figure 31 Pleating over the ends.

Note that this paste layer provides no shell integrity whatsoever. It is only for fireproofing the twine and sealing the shell from lift gases. Regardless of what the size of the shell is, two turns of 30lb recycled kraft is the only thing used to paste in a Maltese break. Allow the shells to fully dry before proceeding to assemble the breaks.

Note that each of the breaks in a Maltese multi-break shell are completed as if they were stand alone shells before being joined together. The only difference between building a single break shell and a shell used in a multi-break is that you leave a hole in the bottom of the shell for the next shell to plug into.

This "divide-and-conquer" method is much easier than the traditional Italian technique of progressively building one break on top of the previous break and applying the vertical spiking with each additional break. The stack-as-you-go method becomes too difficult and cumbersome as the shell size increases to 6" and above.

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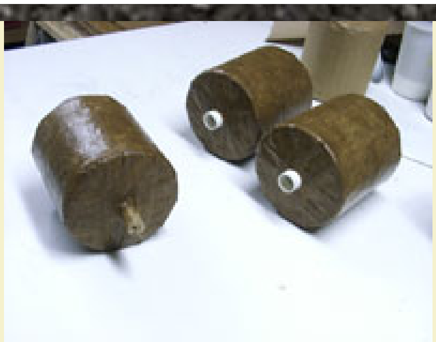

Figure 32 Pasted breaks ready for drying.

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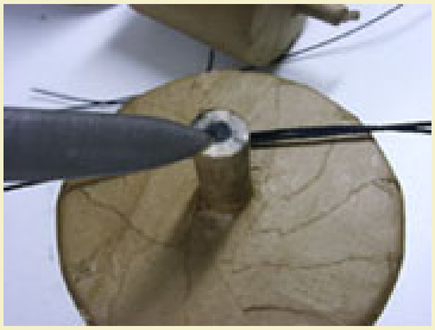
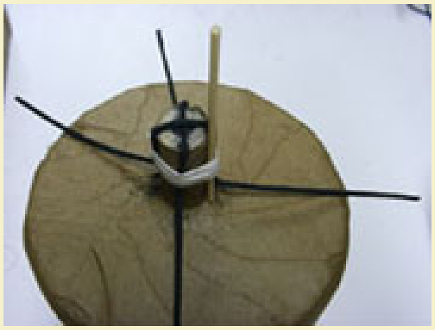
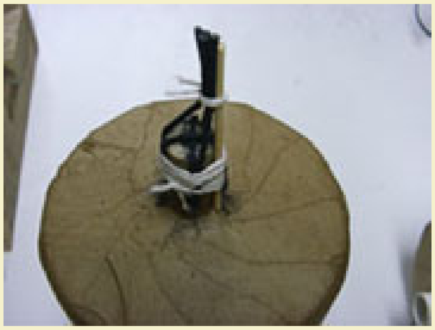

Step 1: Scratching the powder surface.


Step 2: Tying on sticks of black match.


Step 3: Match is folded up and secured to bamboo skewer stick.

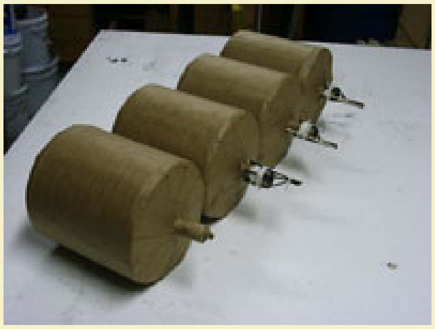


Figure 33 Breaks are ready for assembly.

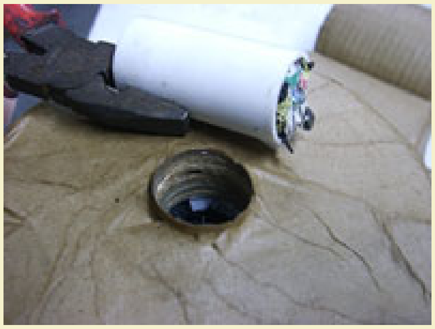


Figure 34 Removing the PVC plugs.

Assembling the Breaks:
Once the paste wraps are dry, the shell is ready to be assembled. You will need to first prepare the spolettes of the second and third breaks, as well as the bottom shot. Tear off the paper that protects the powder core and scratch the surface with a knife as shown in Figure 1. This helps the spolette take fire easier.

Next take two 11" long strands of black match and make an X over the spolette. Use a short stick of bamboo skewer held up against the spolette so that it points straight up. The match will be tied to this to give it support when inserted into the shell above it. Fold the black match down and secure it and the wood splint with a clove hitch, then wrap twine around them several more times as seen in Figure 2.

The black match pieces are now folded back up over the twine and tied to the wooden stick. More twine is wrapped around the spolette to make sure the whole assembly does not get pulled off when the shell above it bursts.

Figure 33 shows all the shells prepared for assembly. The spolette on the top break is not matched until later. The shells will now be stacked on top of each other, starting with the first break. Invert the top break and remove the PVC plug with a pair of pliers, as seen in Figure 34. Now take the second break and push the spolette into the hole (Figure 35). The plug from the second break is removed and the third break is inserted. Finally the bottom shot is inserted in the same way.

Carefully pick up the stack of shells and lay them down onto the shell rolling jig. At this point you will need the shell press described in this month's article in order to proceed.

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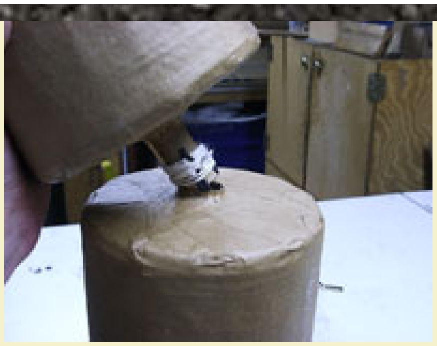

Figure 35 Stacking the breaks upside down.

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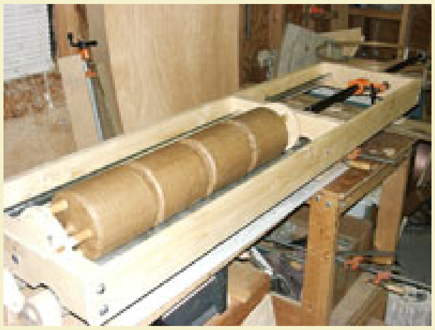

Figure 36: Shell press setup over shell roller.

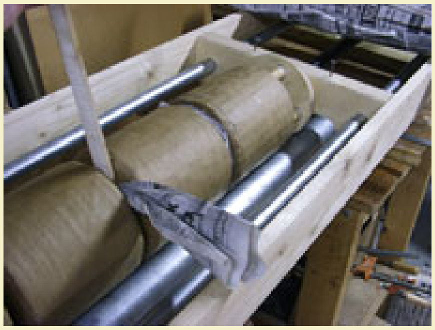

Figure 37: Ramming pasted newspaper between the breaks.

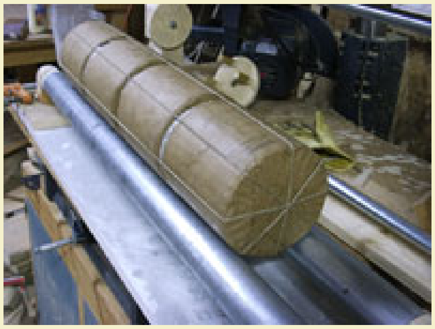

Figure 38 Stringing the breaks together.

Stringing the Breaks:

Once the breaks are aligned inside the press, pressure is applied to close the gaps between the breaks as much as possible. These gaps must now be filled with newspaper which is crumpled into long strips and wiped with a light coating of paste.

Start by tearing full sized sheets of newsprint in half, then crinkle each half up into a long strip. It will take two or three such strips to fill each gap. First apply a slight amount of paste by hand, drawing it across the length of the strip. The damp strip now fed into the gap between two breaks in a spiraling fashion. Use a thin wooden stick to ram the paper in place, rotating the shell as you go. Keep adding paper until it fills almost flush with the outside of the shells.

The purpose of this newspaper is to shim the shells so they do not flex at this joint. The paper also helps to fireproof the area where the shells join so that no lift gases can get into the shells and set them off during lift.

Once all three gaps have been filled with paper, the shell is ready to be strung. While it is possible to string the shell while it remains in the press, it is easier to remove the press so that it does not get in the way. The shell will not uncompress any noticeable amount, so keeping it in the press is not necessary.

Two strands of a good flax twine are used to string around all the breaks and hold them together. There will be six verticals of double stranded flax wrapped around the shell long ways. You can either use two strands at a time, or wrap around the shell twice for each vertical. Tie off to the spolette and pull the string around the shell as tight as possible. The shell is easily rotated on the rolling jig as needed. The twine is tied to the spolette again after all six verticals have been applied. Figure 38 shows the shell after the twine has been applied.

Next you will need to wrap each joint with cotton twine in order to pull the vertical strands even tighter. Four strands of cotton twine are used in parallel to reduce the amount of turns required. The twine is pulled as tightly as possible while spinning the shell on the rollers. Enough twine should be applied to completely cover the gaps between each break.

Alternate Method:

It is also possible to assemble this shell without the use of the shell press, although it is considerably more work. Starting with the separate breaks, only one break is inserted at a time, after which spiking twine is used to hold them together. Starting from the bottom up, the bottom shot and the third break are strung together first, then break two is added, followed by the first break. The newspaper is then weaved between the spiking twine and rammed into place.

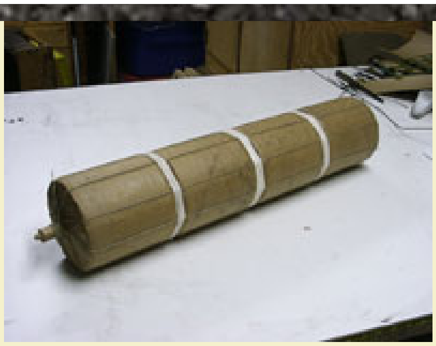

Figure 39 Stringing between the breaks with cotton twine.

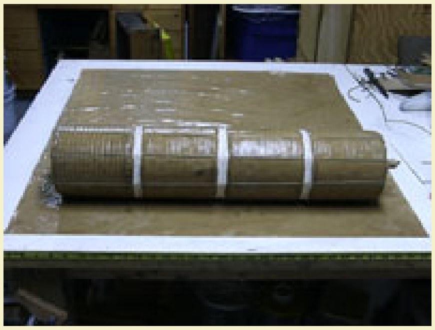

Figure 40 Pasting in the shell.

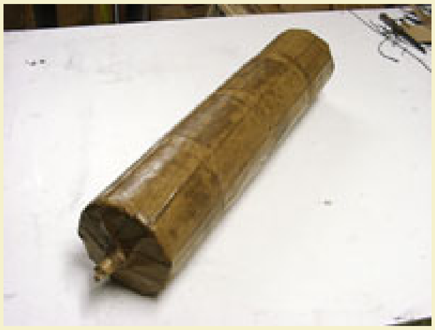

Figure 41 Shell ready for drying.

Note that the shell press method involves only one set of strings for the entire shell, while the manual method gives each set of breaks it's own set of string wrap. It might seem that having only one set of strings holding all the breaks together would fail after the first break broke all the strings. However, the paper in combination with the underlying string will still keep the shell from coming apart after the first break pops the twine and removes the tension it once held.

With Italian shell construction, the verticals that hold the breaks together are also the same verticals that hold the end disks on. Thus, the shell-press method shown here could not be used in the same way for making Italian style shells. The vertical twine holding the breaks together in a Maltese shell plays no role in providing confinement of the individual breaks. Each break is a separate, completed entity that would perform well if fired individually. The outer twine wrap serves only to keep the breaks held together and prevent them from flexing during handling and when being fired from the mortar. Once the shell is airborne, there is only centrifugal forces to pull the breaks apart as the shell rotates. This rotation is usually very slow and the paste wrap is more than enough to hold up against the centrifugal pulling forces.

Final Paste Wrap:
The shell is pasted in with two turns of 50 or 60 lb recycled kraft paper. A sheet wide enough to reach from a little over half the bottom to a little past the spolette is measured and cut to a length of 36 inches.

Apply paste to one side of the kraft sheet, then completely cover the shell with paste. The shell is then rolled one turn in the paper, after which time more paste is applied to the dry paper as it is pressed onto the shell. Work the paper onto the shell so that it conforms around the twine and hugs the shell tightly.

The shell is now rolled in the second turn of paper. Again the paste is applied by hand to the dry paper and worked onto the shell. The ends are ripped and pleated down in the standard method, leaving a finished shell that looks like Figure 41.

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Lift Method:

Maltese shells are lifted in a very ingenious way that, while more labor intensive to construct, has three key advantages: 1) cheap home made rough powder is used instead of black powder, 2) less lift is used than conventional methods require and 3) there is less stress on the shell, reducing the risk of rupture during lift.

Given the ever rising costs of commercial black powder, just being able to use home made rough powder alone is worth lifting shells in this method. However, consider that you can lift this 20 lb shell with only 200g of rough powder, compared with 420g of black powder required by the conventional method!

The basic idea is to contain the slower burning rough powder in a shell-like can, effectively creating a low-power black powder "salute" that sits under the shell. Above this is a plywood disk followed by a thick wad of crumpled up paper. When the lift can explodes, there is a pressure impulse that drives the plywood upward and crushes the newspaper so that it expands to seal the gap around the shell where blow-by gases normally travel. This allows nearly 100% of the lift gasses to be used to propel the shell out of the mortar. The wad of paper also acts as a cushion against the pressure impulse, preventing the shell from enduring a large pressure spike all at once. For more discussion about this lift method, read more about it here.

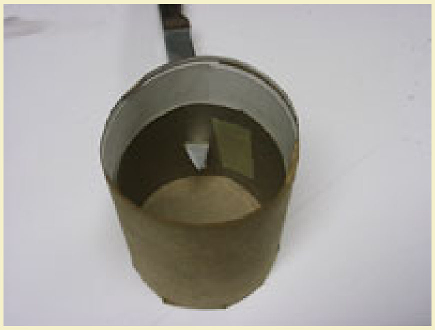

Figure 42: Punching fuse hole in lift cup.

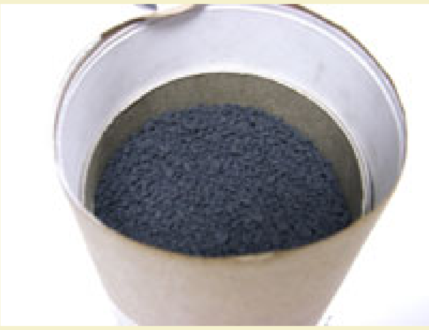

Figure 43: Can filled with 250 grams of 1/8" rough powder.

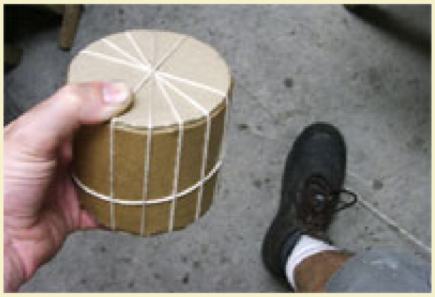

Figure 44: Spiking the lift can with a single strand of cotton twine.

Making the Lift Can:

The lift can is created in the same way that all the breaks for this shell were created. A 24" long strip of 5" wide poster board is rolled along with a 5-1/4" x 24" long strip of 60 lb kraft around a 4" case former (3-1/2" actual diameter). The ends are sliced and folded down as described previously.

Once dry, the 4" can is ready to be charged. The piped match will enter the can from a hole punched in the side. The Maltese make this hole after the can is finished, but I like to pre-punch mine and cover it with a piece of masking tape. I also like to add a turn or two of chip so that the end disk can be held up off the lift charge, which creates a small void that makes it easier to insert the match later. Figure 42 shows a knife being used to punch a hole through both the 4" can and the chipboard liner.

The can is now filled with 200g of rough powder which passes through a 1/8" screen. So the particle size is between 1/8" and dust. For this shell I chose to use 250g of lift, since I want the shell to be higher up off the ground than the low level displays the Maltese desire.

A disk is inserted and tabs are sliced, folded and glued down as usual. The shell is then spiked using a single strand of cotton twine, as seen in Figure 44. Because there is no time fuse or spolette for you to tie off on when spiking the case, you just tie around the case itself and then start your vertical spiking from there. Note the high-tech spiking horse being used to provide tension while spiking (foot on string).

Once the can is complete, it can be pasted in with a few turns of 30 lb kraft, but I personally skip this step. It will work fine without the paste wrap.

Assembly of Lift Components:
You will need to cut a 5-1/2" diameter disk out of plywood or other scrap material between 1/2" to 3/4" in thickness. Cut a small notch on the edge so that the passfire pipe has a place to route past the disk. This disk will land close to the mortar after the shell is fired and can be reused again if found.

The large wad of newspaper is made from about six full sheets of news print that are crinkled into long pieces and then rolled up like a cinnamon roll. The roll should match the outside diameter of the shell.

Figure 46 shows the assembly order for all three lift components. The shell is supported upside down and the components are securely fastened with fiber tape as seen in Figure 47. Be careful not to tape over the fuse hole in the lift can. Also make sure that the fuse hole in the lift can is aligned with the notch in the plywood disk, since that is where the passfire pipe will need to be.

The fuse hole in the lift can now be re-opened, as seen in Figure 48. Before the passfire match is inserted, the bare match should be bent into a hook as seen in Figure 48. This helps prevent it from being pulled out by accident. Push the match all the way to the center of the lift charge inside the can.

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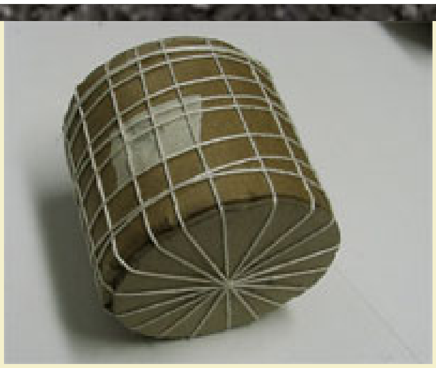
Figure 45: Finished lift can with tapped over fuse hole.

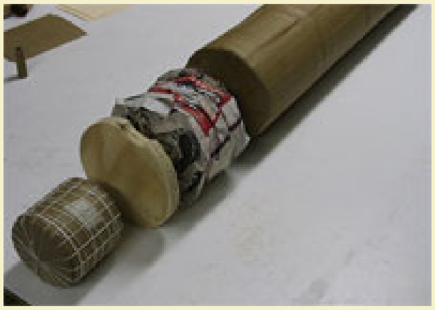
Figure 46: Lift can, plywood disk and paper wadding in assembly order.

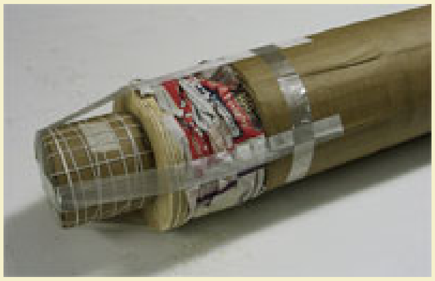
Figure 47: Fiber tape holding lift components in position.

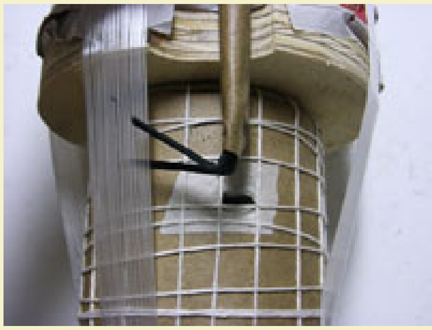
Figure 48: Bending the black match over before inserting leader into lift can.

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Volume 2, Issue 10

6" 3-Break Malta Shell, Part II...

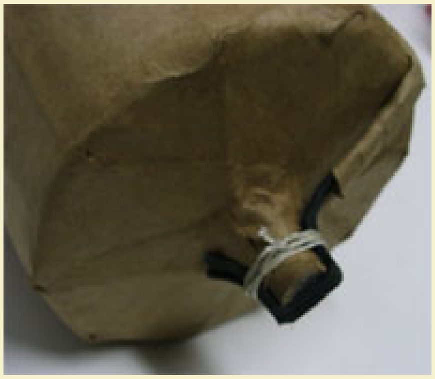

Figure 49: Attaching passfire to the spolette.

The passfire is routed up the side of the shell and tied off onto the spolette as seen in Figure 49. Two sticks of good quality black match should be used to insure quick and sure fire transfer. A delayed passfire can lead to the sad destruction of a lot of work, as the first break goes off in the gun and sends any surviving remains to dangerously low heights.

One little precaution I like to take is a strip of plastic packing tape applied over the entire length of the passfire, taping it to the side of the shell. This helps water proof this critical component, which can be subjected to moisture if the shell is loaded into a dirty gun that has a hygroscopic sludge buildup inside. This sludge can transfer moisture through your shell wrap and into the piped match if the shell is to remain in the mortar for any length of time.

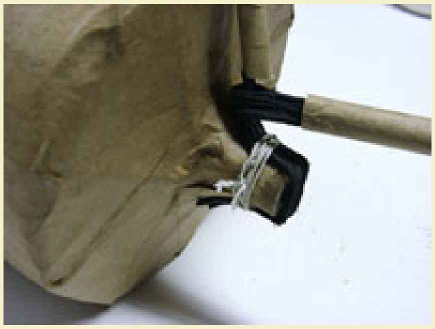

Figure 50: Attaching the leader to the passfire.

The leader is now attached by exposing about 6" of bare match and looping it around the passfire, as seen in Figure 50. The ends are folded around and tucked back up into the match pipe, which is then slid down as far as possible.

Finish Wrap:
Whew, almost done! The shell needs to be rolled in a few turns of 30 lb kraft, which will be a sheet about 45" wide and 36" long. The kraft should overhang the top end enough to provide a good handle when lowering the shell into the gun, as seen in Figure 51. The bottom end is tongue folded and glued down as seen in Figure 52. Some builders use gummed tape or even packing tape to make an X across the bottom. I think no tape looks better and leaves less burning garbage in the mortar.

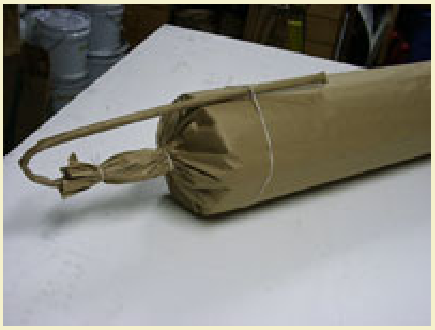

Figure 51: Finish wrap at top of shell.

Some Maltese will tie a string around the joint between the paper wadding and the shell, which can be seen in Figure 53. I'm not sure what this is for other than perhaps to pull in any slack in the paper wrap. A second piece of string or a strip of tape is used at the top to hold the leader down until it is ready for firing.

Some Maltese builders will further decorate their shells with colored paper and bands of colored strips. It is typical to number the shells with large black numbers that indicate what order they are to be fired during the festival.

Firing Notes:
You should not attempt this shell unless you have experience with small and large caliber multi break shells. This type of shell should not be fired from HDPE mortars, as they can not handle the pressure. Use only steel guns! The suggested clearance above the shell to the top of the mortar, as recommended to minimize tumbling in the air, is about 5 inches.

Since Malta is located on a bedding of hard lime rock, it is often difficult for them to bury their steel mortars as deep as they need to be. To get around

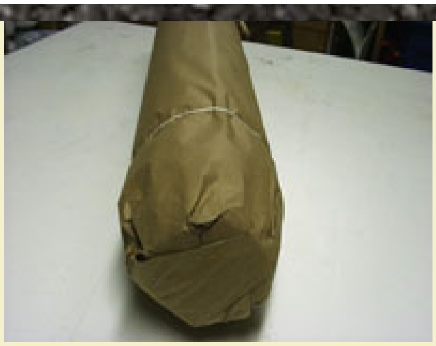

Figure 52: Finish wrap at bottom of shell.

this problem, old tires are stacked up around the exposed length of mortar, and the operators have stone walls to hide behind.

Special Thanks to Bennie Farrugia (at right) and Paul Schembri for sharing their Maltese fireworks methods with America!

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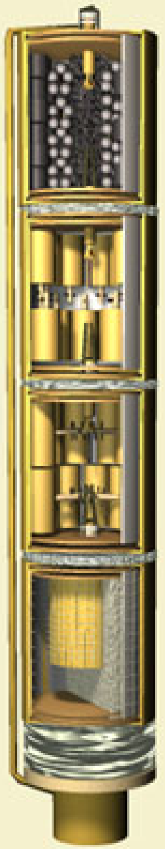
Volume 4, Issue 1

Build This...

6" Compartment Shell

Color Break w/Inserts, Reports & Bottom Shot



Summary:
If you've ever seen a shell break that seems to release more effects than could possibly fit in one break, you have probably seen a compartment shell in action. Compartment shells are constructed like multi-break shells, only the breaks have hollow spolettes between them to allow gasses from the first break to spread to all breaks instantly and break them all at once. The illusion is one single break, even though several separate shells are actually breaking at the same time.

The compartment shell detailed here uses the Maltese shell construction method to produce a symmetrical central comet break with color pistil, followed by a ring of color insert shells, then a ring of reports before ending with a large bottom shot.

Perquisite Reading: Maltese Multi-break Shells
Maltese 6" 3-Break w/Bottom Shot
Maltese Shell Roller
Multi-Break Shell Press
1-1/2" Insert Shells

January, 2004 Issue

Build This:
6" Compartment Shell

Design Notes:
Burst Charges

Tool Tip:
Paper Cutting Station

A Christmas Story:
Fireworks in the Philippines

Class C Corner:
One Bad Mother
Independence Spirit

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Volume 4, Issue 1

6" Compartment Shell...

Page 2

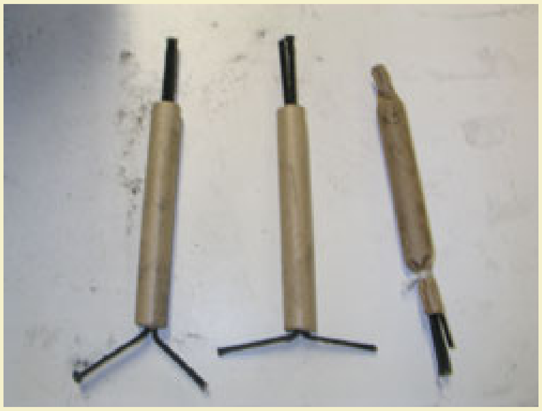

Figure 1: Two pass-through spolettes and one charged spolette.

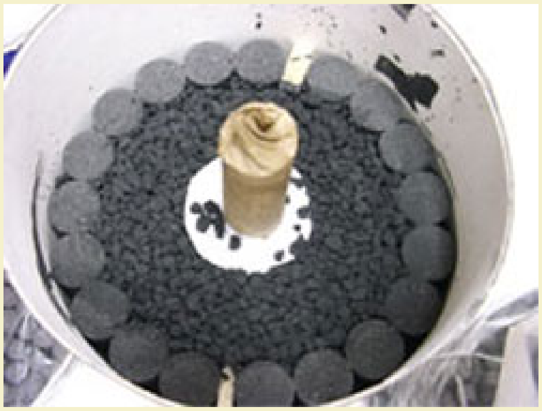

Figure 2: The top compartment, a standard Maltese color break with a 3.5sec spolette.

Introduction:

The more components that are loaded into a single break of a canister shell, the longer the shell case must be to accommodate them. Unfortunately, the ability of a canister shell to resist splitting under the lift forces before leaving the mortar decreases as the case length increases. Longer shells are subject to more compression, and this can lead to side splitting and subsequent flower potting.

It is important not to confuse case length with shell length here. Case length is the length of one single break within the shell, whereas shell length is the sum total length of all individual cases stacked on top of each other. Flowerpot risks also increase as the shell length increases, but not as dramatically as when individual case lengths increase. A long shell made of several smaller breaks has more structural integrity than a long shell made with fewer but longer breaks. Each break adds a "bulkhead" to the structure of the overall shell, providing zones within the column that are not susceptible to bulging or buckling under pressure.

Dividing a single break into several compartmentalized breaks not only increases shell integrity, it increases the amount of components that can be thrown out in the same plane at the same instant. This is useful when you wish to have many concentric rings of effects breaking at different times as they spread out across the sky. Typical compartment shells contain a color break in conjunction with some combination of insert effects that display at calculated intervals.

The only difference between a compartment shell and a multi-break shell is that the spolettes between compartments are just hollow tubes with a few strands of black match running through them. This allows the gasses from the first break to pass into the next breaks in rapid succession, with all breaks appearing to burst at the same time from the perspective of the viewer. This effect sometimes occurs unintentionally when multi-break shells employ poorly made spolettes that can not hold their powder charge against the internal burst pressure of the shell, a phenomenon known as "blow-through."

Construction:

Because this is a larger caliber shell consisting of multiple breaks, the Maltese method of construction is used. Start by preparing four 6" cans using 10" wide strips of poster board that are 36" long (multiple pieces can be added together to get this length). Use 1-1/2" tabs to close in the top disk, which will give you a good 8-1/2" inches of useable can for loading the break contents. It is better to have a can that is too long than too short, since you can always trim the excess when closing the can.

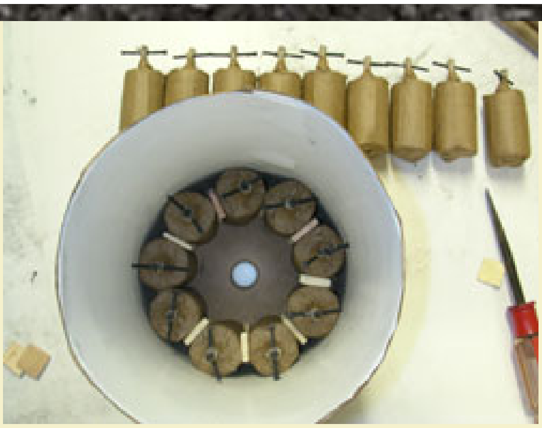

Figure 3: Loading the first ring of insert shells in the second compartment.

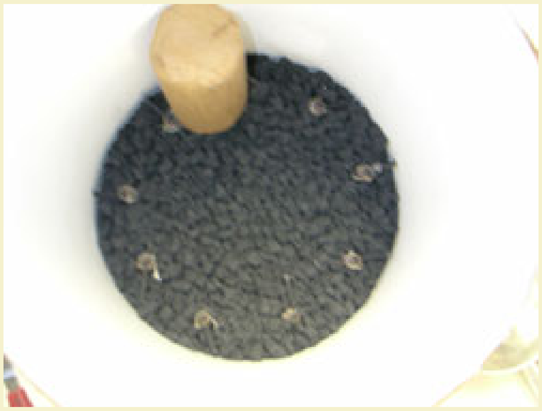

Figure 4: Loading the second ring of insert shells after filling in with rough powder.

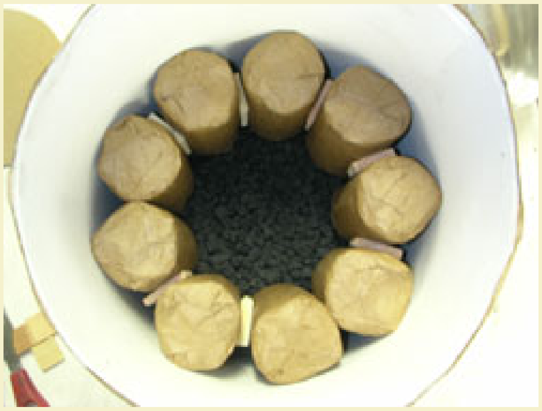

Figure 5: The second ring of 9 inserts wedged in place.

You will need the following disks to make the cans:
8 - 6" disks with 1/4" center hole
6 - 6" disks with 3/4" center hole
2 - 6" solid disks
2 - 4" disks with 1/4" center hole
2 - 4" solid disks

The bottom shot is made as described here, so it is not covered in this article. The spolette for the bottom shot will need to have a 6.5 second delay on it.

The spolette for the first break needs to have a 3.5 second delay, which is about the amount of time it takes for a shell of this size to slowly rotate so that the plane of break is at the optimum viewing angle for the audience (determined by watching many similar shells on video). The spolettes for the top break and bottom shot are rolled from manila file folder paper as described here, except the O.D. only needs to be 1/2" instead of 5/8". This allows the spolette to be made from only one sheet of manila while still being strong enough to withstand very hard ramming. The other two spolette tubes are 4" long and not charged. Figure 1 shows the top spolette along with the two hollow spolettes. Two pieces of black match are fed through the hollow tubes and T'd at the bottom to prevent them from pulling out after being installed in the shell. This match is probably not even necessary, but I include it as an extra precaution to insure that the fire train is not broken.

Loading the Cans:
The first break shown in Figure 2 is loaded as a standard Maltese comet break with color pistil, as described here. I prefer to use streamer type comets for a shell like this so that the central break remains visible as the rings of insert effects surround it. Glitter, flitter, willow and charcoal streamers are all good choices for this break.

The second break is loaded with 18 color insert shells in two rows. The insert shells are constructed as shown here, except they are made to be 2" tall instead of 2-1/2" as shown in the referenced article. These will break 2 seconds after the shell opens, which means the time fuse for them should be cross matched about 1" between centers.

Figure 3 shows how the insert shells are loaded using wedges instead of packing with sawdust behind them. This method is much faster and gives the same results. The idea is to make sure the shells are held firmly in a ring, such that they do not fall out if the can is turned upside down. This is much easier to do using thin wooden wedges than ramming sawdust between each insert.

After the first ring of inserts is installed, 1/4" rough powder is used to fill the center space and the spaces behind the shells. Be sure to plug the bottom hole with a removable plug first. A simple section of 5/8" I.D. tube with a wad of paper tamped into it makes an adequate plug. The rough powder is filled until it reaches the top of the time fuses, as seen in Figure 4.

The second row of insert shells is now installed, placing the fuse end down and wiggling it into the rough powder so that the shell seats on the powder bed. Wedges are again used to lock the ring in, as seen in Figure 5.

One of the pass-through spolettes is now placed on the powder bed as seen in Figure 6, then the remainder of the empty space is filled with rough powder. Be sure to tamp the case while filling so that the powder settles into all the voids.

More...

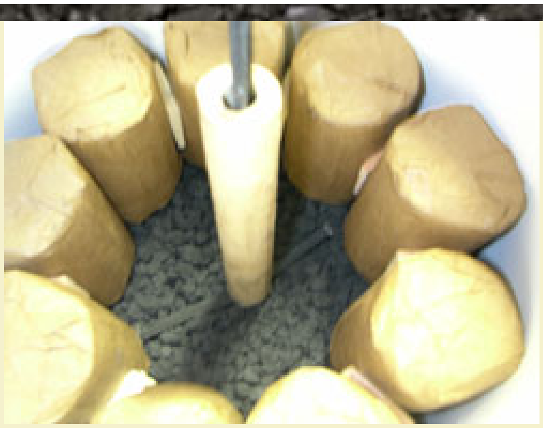
Figure 6: A pass-through spolette put in place before filling with rough powder.

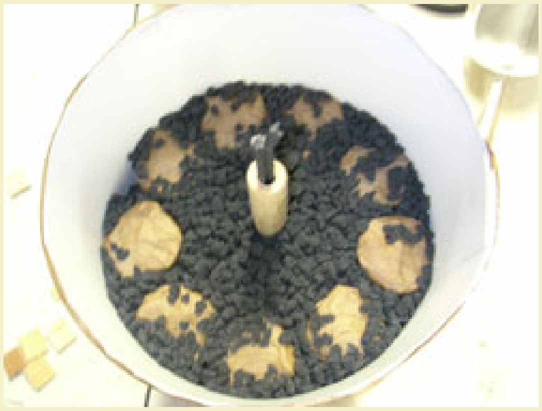
Figure 7: Rough powder is filled around the spolette and all other empty spaces to finish off the second compartment.

6" Compartment Shell...

Page 3

The third compartment is loaded with 20 reports that are timed to go 3.5 seconds after the shell breaks. This will be 1.5 seconds after the ring of insert shells break, giving a big ring of noise before the final bottom shot goes 1.5 seconds later.

The reports used for this shell can be made in one of many ways, but it is better if they are side fused as shown rather than top fused as the insert shells were. Not only do side fused inserts take up less space in the shell, they are less susceptible to having the setback forces drive the fuse into the shell and damage the gas tight seal, which can cause them to break when the shell breaks. If any one report leaks and goes off when the shell breaks, it will set off all the reports at once and just make one loud boom. In shells that contain the reports within the same break as the stars, this type of failure will destroy the stars as well. In a compartment shell, however, the color break can actually survive the detonation of the report break, thus preserving at least part of your hard labor!

The reports shown here were made from spiral wound tube cores that measure 2-5/8" long x 1-1/4" O.D. with a 1/8" wall. The time fuse holes were first drilled in the sides, then covered with a piece of masking tape. A chipboard disk was then glued to the end of each one and allowed to dry. The tubes were then loaded with an increment of sawdust, then filled with flash, then topped with more sawdust. The sawdust is just there to act as a secondary gas leak barrier. An end disk is glued in place after loading and allowed to dry. Spiking the salutes with a good linen flax twine will make a noticeable increase in loudness. After spiking, the salute cases are pasted in with two turns of 30lb recycled kraft. The recycled kraft lays down much easier, shrinks more and makes a better gas tight seal than virgin kraft, which is why I prefer it for all final outer shell wraps.

Once the salutes are dry, you will still be able to see where the pre-drilled fuse holes are. A pencil is now used to punch through the thin paper and tape barrier so that you can insert your time fuse. The time fuses are cut at an angle on the end that goes into the salute. The angled cut exposes a little more powder core and increases the amount of flame transfer, which is important since there is no way to cross match the inside end of the time fuse when side fusing like this. A distance of 1-5/8" is measured between the cut end of the time fuse and the cross match hole, giving you the desired 3.5 sec delay (assumes a 2.2sec per inch burn rate on your time fuse).

The cross matched time fuses are inserted as far as they will go, then hot melt glue is used to seal around the base. White glue may be used, but it will have to be applied in two coats in order to deal with the problem of air-bubble gaps that form when the first

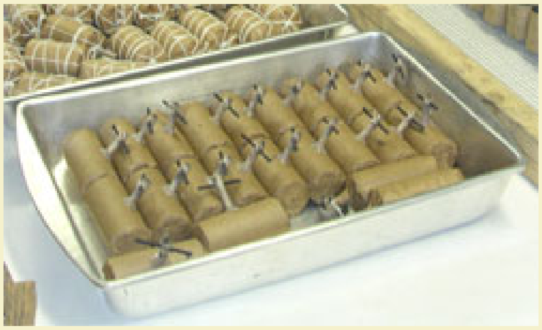

Figure 8: A tray of 20 side fused reports ready for loading.

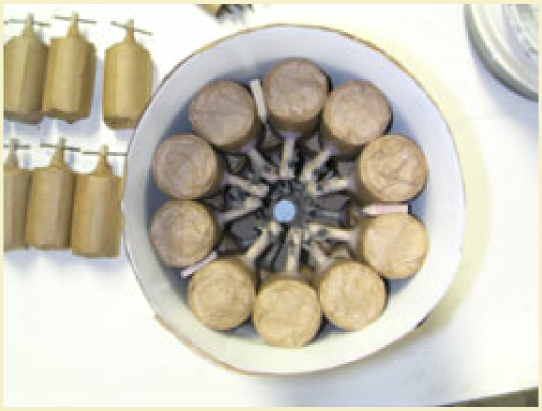

Figure 9: Third compartment is loaded with two rings of 10 reports.

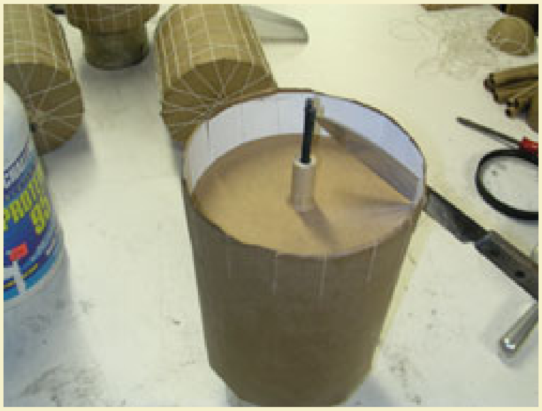

Figure 10: All three cans are closed using the Maltese method.

application dries. So a second application must be applied after the first one dries. Hot melt glue is really much better than white glue when making critical gas barriers like this because of the air gap problem that occurs with white glue.

The completed salutes are shimmed into place just like the insert shells were, as seen in Figure 9. Both rows of salutes can be installed at once as seen in Figure 9, although it is probably best to fill in around the first row with rough powder before installing the second row.

The salute compartment is finished off with a hollow spolette just as the second compartment was.

Finishing the Breaks:
With all three cans loaded, a disk is placed over the spolette on each one as shown in Figure 10. The overhanging case is then slit and folded down as described here.

The spiking for this shell was done with the linen flax twine sold by Pyrosupplies. A strong twine of consistent thickness is important for getting good symmetrical breaks out of any canister shell, and the 8 strand variety used here actually allows less than the conventionally prescribed number of verticals to be used. Only 24 verticals was used as opposed to the 32 traditionally recommended for 6" canister shells. Figure 11 shows the wider horizontal spiking used for the two shells containing inserts.

While a traditional Maltese comet break requires a solid layer of spiking using a special jute twine as shown here, I have found that this tedious spiking method can actually be replaced by the Italian style spiking when using a good flax twine. The lower left shell in Figure 12 shows the spiking used on the comet break, the results of which can be seen in the photo at the end of this article.

The three breaks (along with the bottom shot not shown) are now pasted in with two turns of 30lb recycled kraft as described here. Note the use of protective covers over the black match that protrudes from the two hollow spolettes.

Finishing the Shell:
At this point the shell is assembled and finished just like any other Maltese multibreak shell, which is detailed here. Figure 13 shows one of the compartments with the hollow spolette mating with the break above it. Figure 14 shows all four shells being squeezed together on the shell press, with newspaper rammed tightly between the breaks. Note that the paper is not rammed all the way flush with the outside of the casing. This gap allows room for the cotton twine applied in Figure 15 to squeeze down on the six verticals that wrap the shells length. Strong tension on the outer vertical spiking helps keep the shell rigid and strong for storage, handling and of course when coming out of the gun.

The finished shell weighs in at about 18 lbs and is lifted with 250g of rough powder passing through a 1/8" screen.

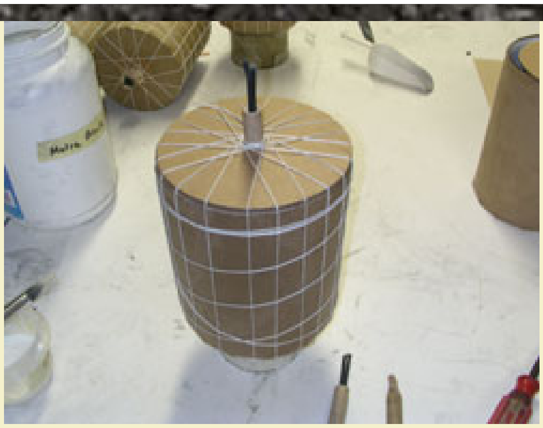

Figure 11: Spiking with linen twine: 24 verticals and wide horizontal spacing on the insert compartments.

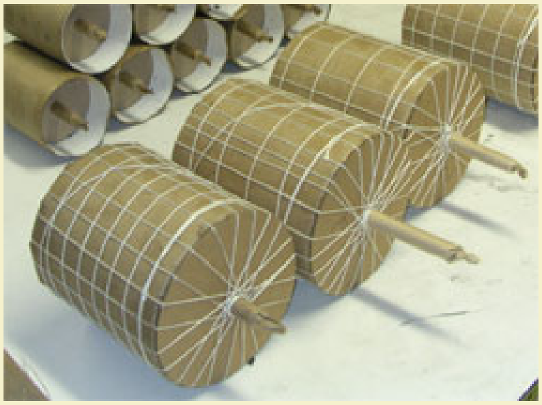

Figure 12: All three compartments spiked. Note the closer spacing horizontal spiking on the color break.

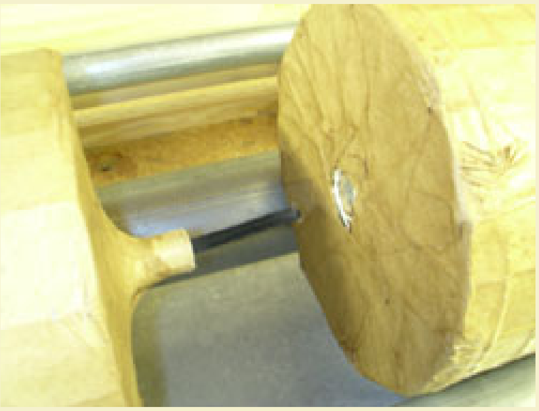

Figure 13: Stacking the breaks on the shell press.

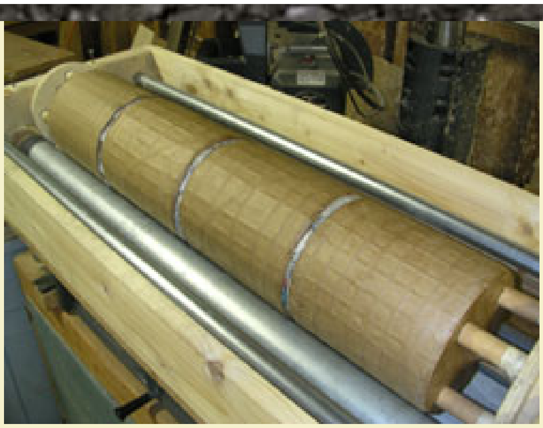

Figure 14: Newspaper rammed in place while press aligns shells tightly together.

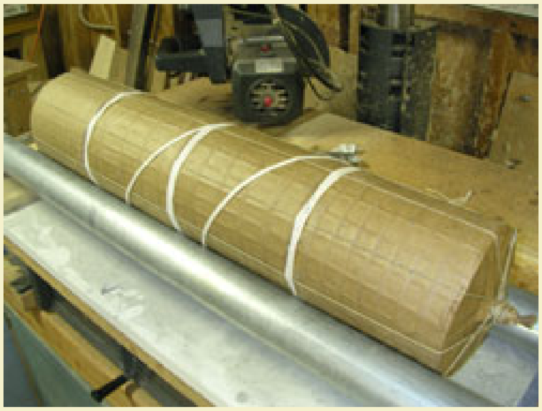

Figure 15: Eight verticals hold shells together, with cotton twine wrapped tightly between breaks to tighten vertical twine.

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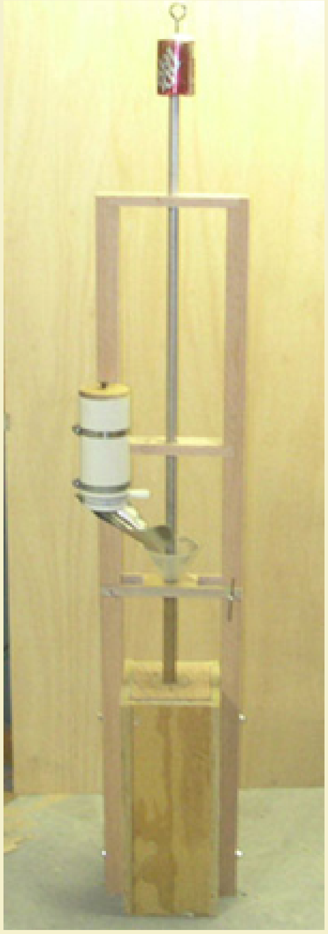
Volume 5, Issue 3

Tool Tip...

Page 1

Maltese Driver Ramming Tool

by **Kyle Kepley**



Materials:

- (2) 8" x 18" plywood, 3/4" thick
- (2) 6-5/8" x 18" plywood, 3/4" thick
- (2) 2" wide x 54" long x 3/4" thick red oak
- (2) 2" wide x 36" long x 3/4" thick red oak
- (2) 2" wide x 16-1/2" long x 3/4" thick red oak
- (1) 2" wide x 8-7/8" long x 3/4" thick red oak (trim to size)
- (2) 1/4" wide x 10-3/8" long x 3/4" thick red oak
- (1) 2" wide x 4" long x 3/4" thick red oak
- (1) 6" wide x 5-7/8" long x 3/4" thick red oak (trim to size)
- (2) 11-3/8" long 5/16" threaded rod
- (4) 5/16" nut
- (4) 5/16" washers
- (1) 7" or longer 3" I.D. PVC pipe
- (1) 1-1/2" long 10-32 taper head machine screw
- (1) 10-32 nut
- (2) 1-1/2" long 1/4" dia aluminum rod
- (1) 2" long 1/4" dia aluminum rod
- (1) 2" long 1/8" brass rod
- (1) 1-1/2" long 1/8" dia brass rod
- (1) 42" long 3/4" dia aluminum rod
- (1) aluminum soda can
- (1) 1/4" eyelet
- (1) 44" long bungie cord
- (1) 3-3/4" wide x 8" long piece of aluminum flashing
- (1) plastic funnel, 7/8" O.D. and just over 3/4" I.D. at throat
- (1) 1/2" thick polyethylene chopping block
- (2) 6" hose clamps
- 10 lbs lead
- 40 lbs concrete

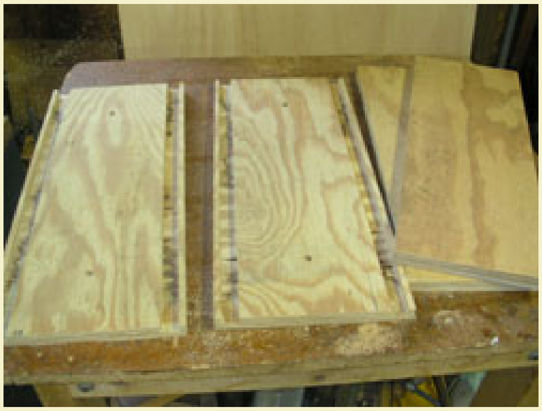


Figure 1: Pieces cut for the base box that will hold the concrete.

Introduction:

I am calling this tool a "Maltese" driver rammer because I first saw the design in a video produced by Toni Busuttil, who uses it to ram thousands of drivers each year for the large wheels used in Maltese festivals. It could very well be a common case loading concept used by many manufacturers in many countries, I just don't know the history behind it. In principle, it is really just a very large and somewhat automated version of the rod and funnel method used to charge lance tubes. The ram rod is both the consolidation piston and the "hammer," using the momentum of the rod itself to create the ramming force.

This tool will allow you to load drivers in about half the time required by either hand ramming or pressing. The reason why it is so fast is that no time is wasted picking up and putting down tools, extracting rammers, scooping powder from a bowl and leveling it off etc. You simply flip a lever to dispense a measured amount of powder into the funnel, then give six to eight whacks on what is essentially an impact hammer. Once the case is locked into the fixture, the clay nozzle, 14 increments of fuel plus the clay end plug can be rammed in about three minutes.

The design shown here was made specifically for 3/4" I.D. drivers, although you could easily modify it for other case sizes. I find that the 3/4" I.D. driver is the most useful size for wheels, girandolas, end burning rockets and large tourbillions, all of which can be produced on this one machine. Thus I did not find the need to complicate the design with the ability to handle other rammer sizes or adjustable powder increment sizes. Like Toni's machine, it is designed to do one thing at one size and do it very well!

While Toni's machine was made from metal, I have produced one using wood and standard hardware store parts in order to make the tool more accessible to the average pyro hobbyist. This is not an exact replica of Toni's machine, as I just built it from memory using the basic concepts as seen in the video.

The rammer consists of a sturdy frame made from red oak, which is fixed to a heavy concrete block encased in plywood. Red oak was chosen for its strength and dimensional stability, thus it should not be substituted with pine, poplar or other light weight woods prone to warping or splitting. The ram rod is a ¾" O.D. aluminum rod obtained from a scrap yard, but brass, stainless steel or other non-sparking metal could also be used. The most difficult to find component may actually be the funnel, which must have a nozzle that conforms to the size you need. I purchased mine from U.S. Plastics, although I was not able to locate it on their website at the time of this writing.

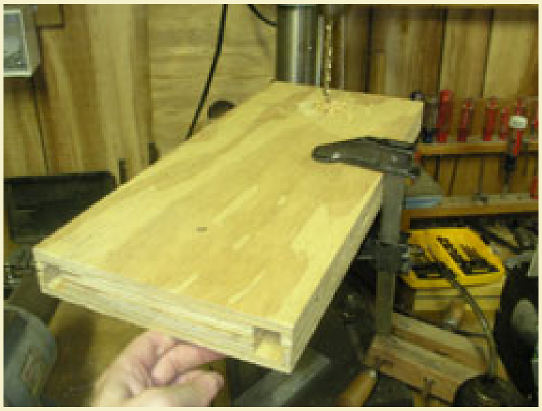


Figure 2: Clamping the opposing sides of the base box together when drilling the 5/16" tie-rod holes.

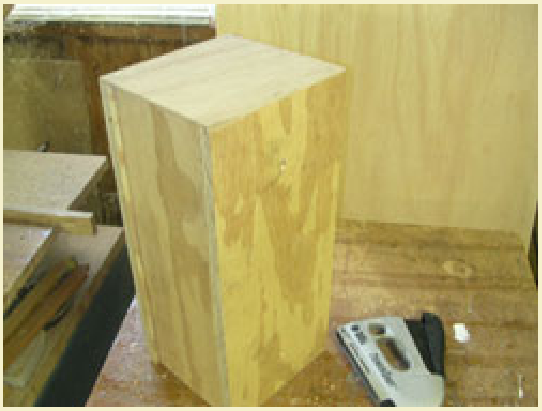


Figure 3: After the box is glued together, the bottom is closed with a scrap of thin wood to hold in the wet concrete when the box is filled.

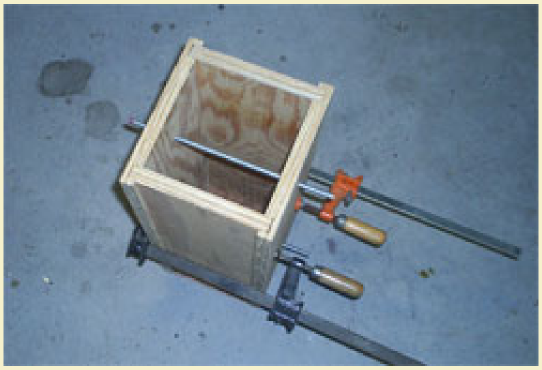


Figure 4: The two tie rods are run through the side holes prior to filling the box.

Building the Base:
The base on which the frame is built consists of an 18" tall block of concrete, which provides a rock solid and vibration free surface to ram against. The heavy weight also helps keep the frame from rocking, moving or tipping over easily, making support legs or tie-downs unnecessary.

The concrete will be cast in a plywood form box, which is left in place once the concrete is dry. Figure 1 shows the four pieces cut to the dimensions given in the material list. Note that two sides have a 3/4" wide trough located 1/4" from each edge, which the other two sides will slide into. Before gluing the box together, clamp the two side pieces together and drill a 11/32" hole centered and 4" from the edge of both the top and bottom, as seen in Figure 2. The holes should run all the way through both pieces, and will allow two 5/16" threaded tie rods to pass through the box before the cement is cast.

After the box is glued together with wood glue, the bottom is covered by stapling a small scrap of thin wood or thick cardboard to keep the cement from seeping out during the pour. Figure 3 shows the bottom cover stapled in place.

Next you will need to cut two pieces of 5/16" threaded rods that are 11-3/8" long, then pass them through the holes in the side of your box so that equal amounts protrude from each side. The rod should stick out a minimum of 1-3/4" beyond the edge of the box. Be sure there are no problems threading the nuts onto both ends of the rod before pouring the cement, because there is no hope of replacing them once the concrete is cast. Figure 4 shows the completed box ready to be poured.

You will need to mix up about 40 pounds of concrete to fill the box, which will consume a little less than one gallon of water. It is easiest to do this in a plastic tub, using a shovel to mix the concrete. Don't be tempted to mix the cement with your hands as it will burn your skin.

Once the cement is mixed to a muddy consistency, simply shovel it into the box and occasionally rock the box back and forth to settle out any air bubbles. Do not fill the box completely flush with the top, leave a little space of about 3/8" for the top cover to fit into, as seen in Figure 6.

Once the box is filled, place a sheet of thin plastic food wrap over the top and use a rubber mallet to tap in a precisely fitting block of oak. Use the mallet to help consolidate the concrete while making sure the top block is level before leaving the cement to dry overnight. You will need to remove this top block later, so leave some sticking up to get a grip on rather than pounding it flush with the box top.

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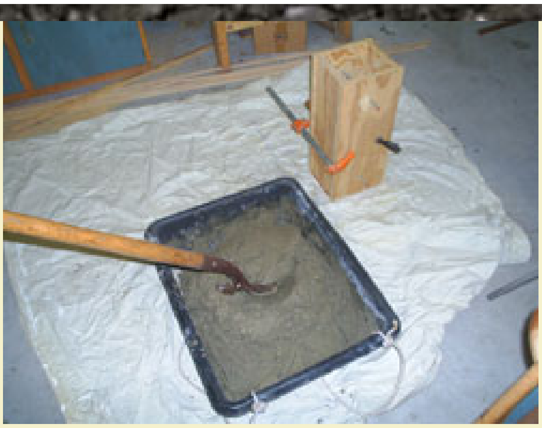
Figure 5: Mixing 40 lbs of cement in a plastic tub using a shovel.

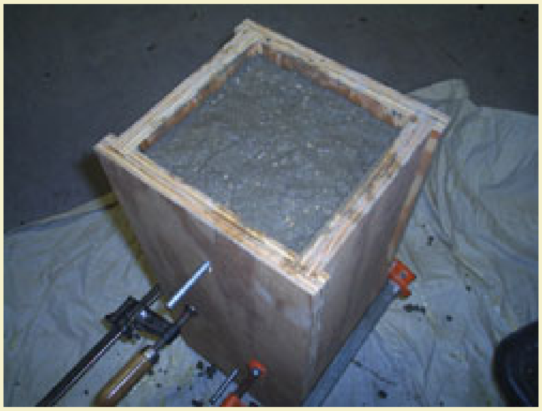
Figure 6: The box is filled to about 3/8" from the top.

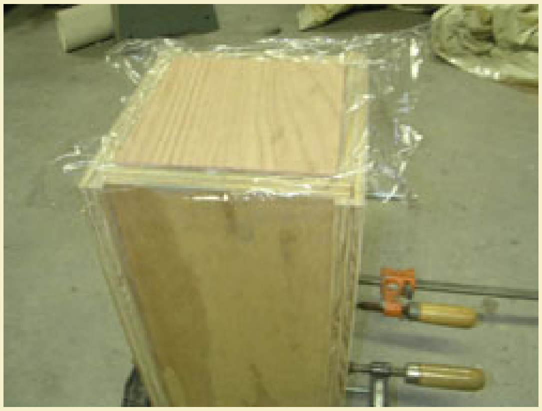
Figure 7: A sheet of thin plastic food wrap is placed over the wet cement, then the top block is tapped into place using a rubber mallet.

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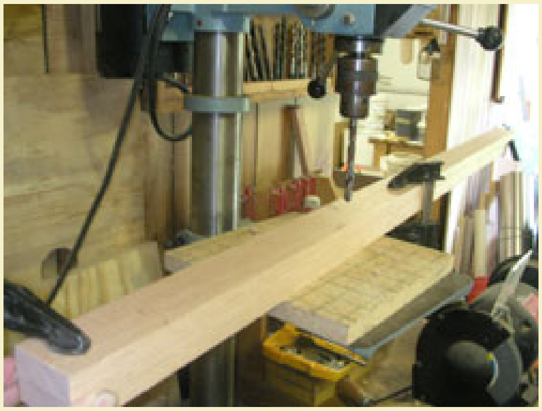


Figure 8: Clamping the 54" long and 36" long frame pairs together when drilling the tie-rod holes.

Building the Frame:

The frame is constructed out of 2" wide boards cut from standard 3/4" thick red oak. You may be tempted to use the stock 1-1/2" wide boards in order to avoid having to rip 2" wide pieces from a wider board, but this will leave you only 3/8" of wood on each side of the 3/4" diameter holes in the cross member pieces. This may not cause a problem, but I just wanted the extra 1/4" buffer for added strength. Thus I used an 8 ft long 1x8 as the material to build the frame. Cut off a foot long piece of the 1x8 to use for the top block and the powder dispenser lid, then rip the remaining 7 foot board into three 2" wide pieces. One of these boards will be cut into two 36" long pieces, then the other two will each be cut to produce the 54" and 16-1/2" long pieces.

Take the 54" long pieces and place them next to the base block so that you can mark where the threaded rod holes will need to be drilled. Once the center lines for the tie rod holes are marked, clamp the 36" piece to the 54" piece and drill through both of them with an 11/32" bit as seen in Figure 8.

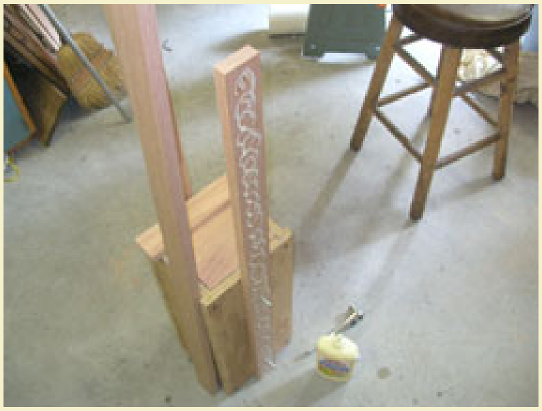


Figure 9: Using wood glue to laminate the 36" and 54" long frame members together.

Next place the 36" long board of each pair onto the tie rods. Test fit the 54" long piece to make sure everything lines up, then remove it and spread wood glue on the entire outer face of the 36" piece as seen in Figure 9. Now install the 54" long piece onto this glued area and secure with a washer and nut for each of the two tie rods. Use C-clamps or bar clamps to secure the two pieces of wood together while the glue dries, as seen in Figure 11.

You will need to prepare the two cross member pieces before gluing the 16-1/2" piece onto the side frame. These pieces measured 8-7/8" long for me, but could be slightly different based on how wide your base box turned out to be. Just measure the distance between the inside of the two 54" long boards right above the base to see how long you need to cut the two cross member pieces. These cross members will be set into place as spacers when attaching the 16-1/2" vertical frame member, so don't make the mistake of gluing them or allowing glue from laminating the vertical pieces to squeeze out onto the cross members and effectively glue them in place. Figure 11 shows the two cross members set in place with various clamps being used to hold the pairs of vertical frame members together.

Before proceeding to the next step, you will want to be sure your ram rod will fit through a 3/4" hole drilled through a scrap piece of your oak. If the rod binds, you will either need to have your rod turned down on a metal lathe or drill a slightly larger hole. The problem with making a slightly larger hole is that wood boring bits are not available

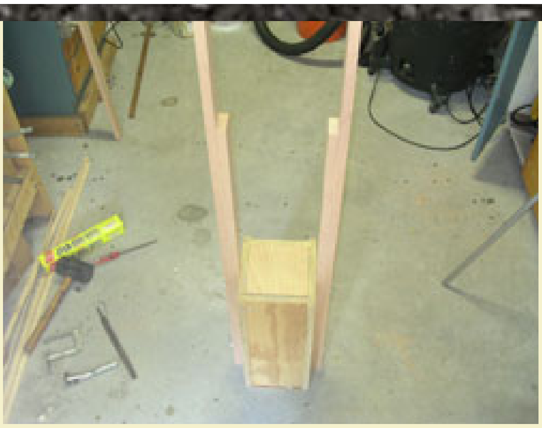


Figure 10: The tie rods are used to clamp down the side members using a washer and nut on each one.

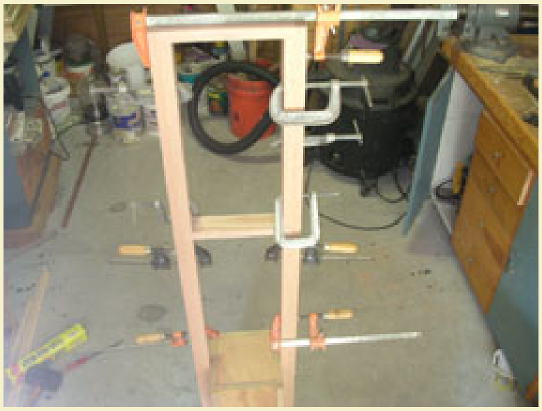
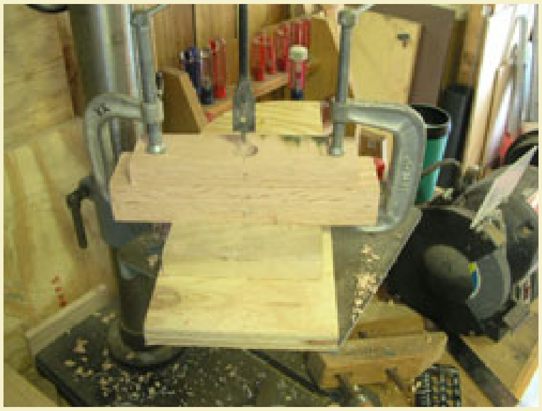


Figure 11: The 16-1/2" segments are now glued and clamped into place, while the unglued cross members are laid in place for spacing purposes.



in small enough increments to find the next size up you would need, since you only want the hole to be something like 1/32" over the diameter of your rod. One way to get a slightly larger hole out of a spade bit is to chuck it up and whack it slightly with a hammer so it is no longer perfectly straight. This causes it so spin off center and drill a slightly over sized hole, albeit in a crude and unmeasured way that should only be done if you don't mind sacrificing your drill bit to the cause. Many times these spade bits manage to get tweaked and spin off center on their own through normal use, as mine did.

Once the glue between the vertical frame members has dried, remove the cross members and clamp them in a stack as seen in Figure 12. A third shorter block will be used as a template when making the funnel block, which can be seen on top of the stack. Drill a centered 3/4" hole through all three blocks as seen in Figure 12. Be sure to mark a line across the front face of all blocks so that you can orient them in the frame to match the same order and position they were drilled at.

Next you will install the two cross members back into the frame using two screws running through the side of the frame to secure them. It is important to run the rammer rod through both cross members so that they are aligned correctly before drilling the screw holes and securing them in place. Failure to do this may result in misalignment that causes the rod to bind when passing through both holes.

The top block on the ramming base now needs to be modified so that it can accept interchangeable bases. This is done by cutting a hole out of it which will match the diameter of the ramming nipple bases that you plan to make. I chose a diameter of 2-7/8" because it matches the diameter of the aluminum base on my rocket tooling spindles made by Rich Wolter, just in case I ever modify this rammer to handle interchangeable rocket drifts. It is important that this hole be centered at the point where your ram rod will strike the board, so the first step is to slam the rod into the board to create a marker, then find the center point of the resulting 3/4" indentation. To cut the hole, I drilled a 1/16" hole at the center mark and then used a pin jig on a router table to cut the hole. A hole saw can also be used if you don't need odd sized holes like the one I needed.

Since this ramming tool is designed specifically for producing 3/4" I. D. end burning drivers, a simple base is constructed as seen in Figure 14. A 1-1/8" long segment of 3/4" dowel rod is rounded off at one end and fitted with a brass center pin so that the resulting end plug will have a centered indentation in the clay to make drilling out the vent easier. A small hole is drilled through the side of the wooden dowel and through the brass pin, which is fitted with a small nail to keep the pin from pulling out. The wooden plug is then glued into the base to finish this home-made ramming base. If you prefer to use more sophisticated choke designs for end burning rockets or other devices, then you will need to have your tooling on hand to proceed to the next step.

The last component required to finish the frame is a hinged funnel plate as seen in Figure 16. This piece is made from a 4" long segment of 2" wide wood that has two 1/4" wide support bars glued to each side. The hole in the center is actually two holes with

Figure 12: The three cross members are clamped together and drilled all at once to insure proper hole alignment and avoid binding the rammer.

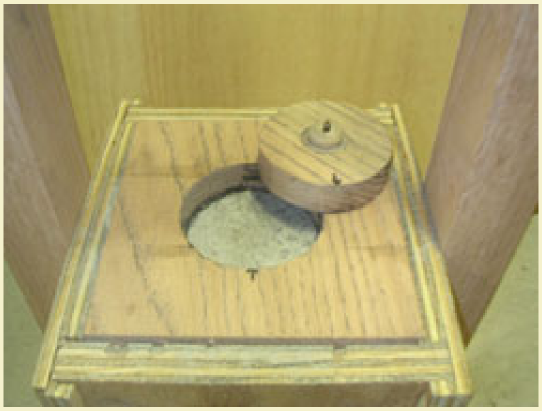


Figure 13: A hole is cut at the rammer center point on the base top plate so that interchangeable ramming bases can be used.

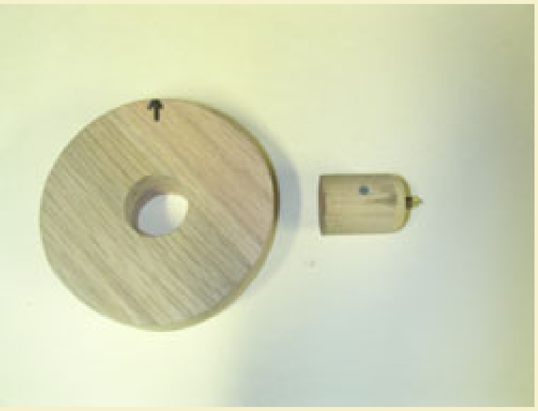


Figure 14: Components of a 3/4" ramming base with center marker for making drivers. Note small nail holding the brass center pin in place.

different diameters: the top one is 7/8" so that the funnel will tightly fit in place, while the bottom hole is 1-1/8" diameter or whatever O.D. your driver casings require. Since common wood boring bits go from 1" to 1-1/8" with nothing in between, I just hand roll my drivers to be 1-1/8" O.D. when they dry.

Drilling the double set of holes for the funnel plate can be a bit tricky. You must first mark the center point using the hole template you created in Figure 12, which is done by clamping the template to the bottom of the piece to be drilled and using your 3/4" bit to pass through the template hole and mark the center on the board to be drilled out. Don't go very far with the 3/4" bit, you only need it to mark a center point for the next bit you will be drilling with. Next remove the template block and use a 1-1/8" diameter bit to drill half way through the block. Finally you will finish the hole with the 7/8" bit going the rest of the way through the wood. It is helpful to start with a longer piece of wood when drilling the holes so that the clamps do not get in the way when the template block is in place, then cutting the block down to the desired 4" length once the holes are finished.

Two 1/4" wide strips of oak must next be cut from some leftover scraps of oak in order to make the support bars for the funnel block. I find it easiest to use a band saw to slice thin strips of wood like this. The length of the strips should reach the full width of your frame as seen in Figure 16. Use wood glue and clamps to fasten the two wood strips on either side of the funnel block as shown.

The funnel used here must be slightly larger than 3/4" I.D. at the throat so that the rod can easily pass through it, and preferably not have much angle to the sides of the throat. I had to cut the throat length back on this one because it closed off at less than 3/4". Just find a funnel that is pretty close to the right size, insert the rammer and make a mark at the point where the rammer jams in the throat, then cut the nozzle back to this mark. If the funnel doesn't fit very tightly into the hole you drilled, use hot glue to lock it in place. Otherwise the rammer bar will occasionally catch it on the way up and knock the funnel out.

The funnel block is mounted using a set of 1/4" diameter aluminum pins on the left side which allow it to pivot up out of the way when loading and removing casings. The right hand side uses just a single removable pin on the front, which has a T-handle to make pulling it out easier. Without this pin to lock the funnel block down, the ram rod may occasionally rub against the side and lift the funnel block up off the case during use.

This arrangement is a simple design that is fast to use, but is setup for one specific length of driver tube. You would need to make a new set of pin holes for each different length of tube that you plan to work with. For my own tubes I am using a length of 7-1/2".

When drilling the holes for your pivot pins, you must first have a casing of the exact length that you plan to use. Place the casing on your ramming block and then insert it into the bottom hole on the funnel block so that the funnel block is sitting at the proper level that it needs to be at. Drop the ram rod down through the funnel and to the bottom of the driver tube, bringing everything into alignment.

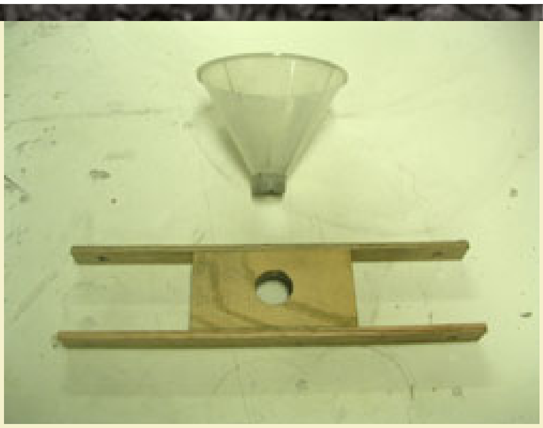


Figure 15: The funnel plate is made using the shorter cross member in Figure 12 as a drill guide. Two ¼" wide support bars are glued to each edge.

Make sure the funnel block is level, then clamp it down so that it doesn't move when drilling the pin holes. The pin holes are 1/4" diameter and run about 3/4" deep.

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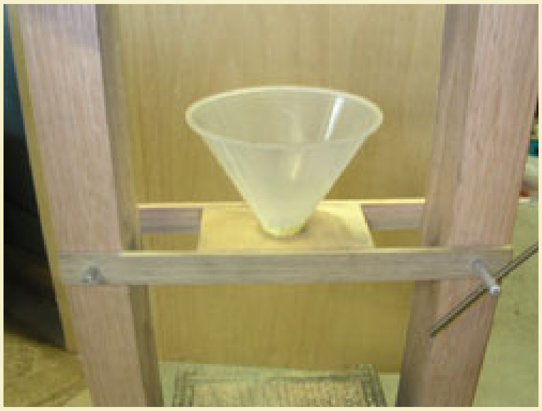

Figure 16: The hinged funnel plate set in place with the right-hand lock pin.

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Maltese Driver Rammer...

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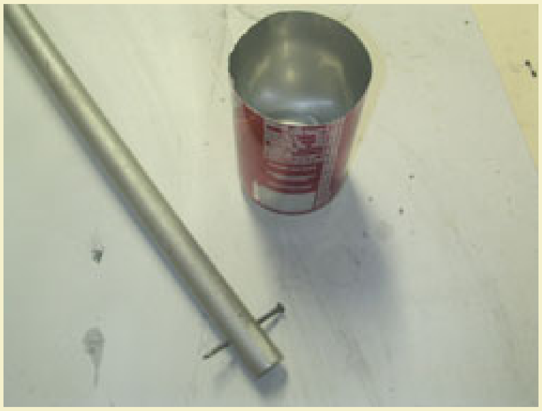

Figure 17: A hole is drilled through the top of the ramming rod so that it accepts a nail. The top of a soda can is cut off so it can be used as the form for casting the top weight.

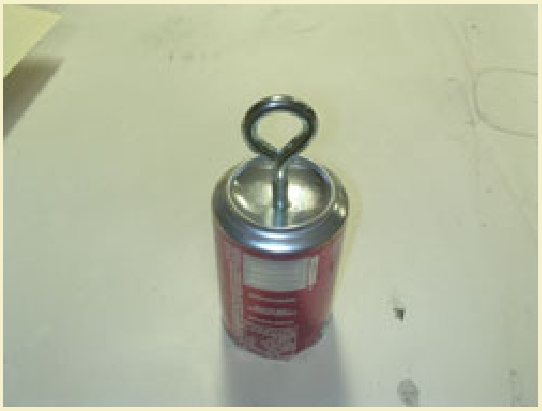

Figure 18: The bottom of the soda can is fitted with an eyelet so that it can be suspended from bungee cords or springs.

Casting the Rammer Weight:

Since the ramming rod is both the rammer and the "hammer" with this type of machine, the weight of the rod needs to be increased in order to give it enough mass to compact the powder well. In order to give the rammer an overall weight of about 10 lbs, a lead weight is cast onto the top of the rod using a soda can as the form. Simply take any soda can and cut off the top, then fill it with lead while holding the rod at its center and you will have a 10 lb rammer. To insure that the rod never pulls free of the lead, a nail is placed through the rod at the end as seen in Figure 17. An optional eyelet can also be fixed into the bottom of the can prior to pouring the lead. This eyelet can be used to suspend the rod from springs or a bungee cord in order to make lifting the rammer easier on your arm. I personally find the overhead suspension unnecessary as it doesn't seem to change the amount of work required by much but does undesirably reduce the impact of the rammer.

Lead can be easily melted on a Coleman propane camping stove. I prefer to bury the tank in the ground so that it can't tip over, then surround the melting pot with bricks so that it also can not fall off the stove and create a lead splashing hazard. Be sure to do this out doors, as lead fumes are likely given off during the melting.

Bury the soda can to be filled in the ground as seen in Figure 20, which helps insure that it won't spill once filled with molten lead. The ram rod is held in place while the lead is poured in around it, then held for about five minutes until the lead solidifies. The solidified weight can then be pulled from the ground and submerged in a bucket of water to cool it off. Be sure to wear long pants, long sleeve shirt, gloves and safety goggles while working with molten lead.

Making the Powder Dispenser:

The powder dispenser is an extra accessory that gives an added measure of efficiency to the loading process when using this machine. It is not a necessary component if you just want to measure out your increments by hand and dump them into the funnel in between rammings. However, when you are doing 14 increments per driver and making many drivers at a time, the small bits of time saved with the powder dispenser add up to a substantial overall time savings. The powder dispenser also gives you an added measure of safety, since the powder being used to load the drivers is totally enclosed during the whole process, as opposed to an open bucket of powder required when scooping out increments by hand.

The powder dispenser shown here is designed to quickly dispense a 1/2 table spoon increment of granulated powder each time a lever is

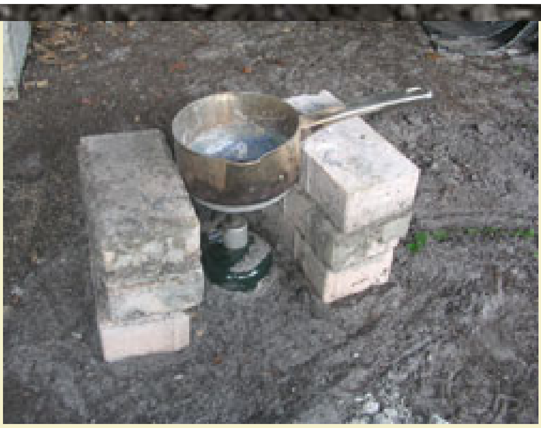

Figure 19: Using a Coleman propane burner to melt 10 lbs of lead out doors.

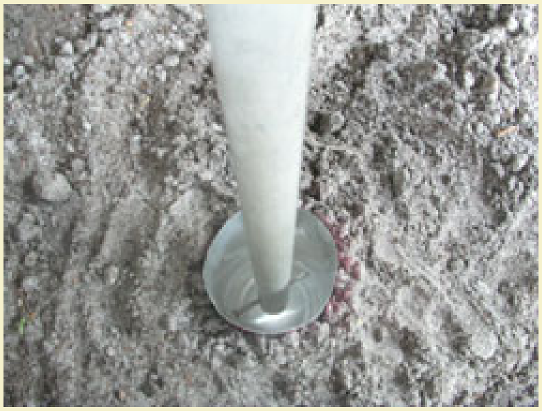

Figure 20: The nail end of the ramming rod is placed into the buried soda can, which is then filled to the top with lead.

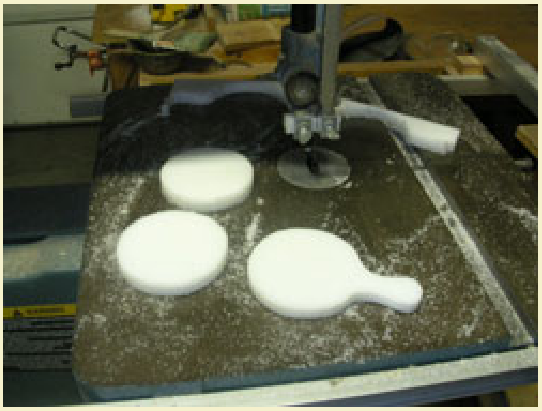

Figure 21: Cutting the 3" diameter disk set out of the chopping block material, which will be used to make the powder dispenser.

flipped. The powder must not contain metal additives such as titanium or iron filings, otherwise jamming or damage to the dispenser could result if hard metal particles worked their way between the rotating disks. The dispenser is designed to fit into the bottom of a 3" I.D. PVC pipe, which will serve as the powder store that feeds the dispenser.

The dispenser is constructed from three disks cut from 1/2" thick polyethylene chopping blocks sold in Home Depot. You can use a compass to draw out a 3" diameter circle, or you can use the inside of a short segment of your PVC as a circle template to be sure you have the exact size that will fit snug into the pipe (since the I.D. of PVC can vary by small amounts and is not perfectly round). One of the disks will have a small lever coming off one side, which you can free hand to any shape you desire. Figure 21 shows the three components after they were free-hand cut on a band saw.

Once you have your three disks cut, you can clean up the edges on a sander and then stack them on top of each other using squares of double sided carpet tape between them so they don't slide around. The tape is only a temporary method of holding them together during the drilling process and works much better than trying to clamp the pieces together somehow.

The first step is to drill your center hole, which will be a small hole about 1/8" or 3/32" to hold the machine screw used as the central pivot point. The machine screw should be long enough to extend beyond the bottom of the three disks by enough to thread a nut onto it. If you used the PVC circle template to draw your circles, you will need to locate the center point of the top disk so you know where to drill. This is best done by drawing a 3" circle onto a sheet of cardboard and cutting it out, then centering the paper disk over your center-less plastic disks and punching a nail through the paper and into the plastic to mark the center, as seen in Figure 22.

Once your center hole is drilled, drop the machine screw into it and proceed to drill a 1-1/8" diameter powder increment hole through all three disks. This 1-1/8" hole will give you a 1/2 table spoon increment of powder as long as you are using 1/2" thick plastic. If you are using a different thickness of plastic or want a different increment size, you will need to trial and error the correct size hole before doing this step.

After the increment hole is drilled, the three disks are separated using a screwdriver and the carpet tape is removed. The next step is to cut a special notch in the middle plate, which will allow a brass pin to connect the top and bottom plates together to that they won't rotate when the middle plate rotates. This connecting pin also serves as a stop limit for the rotation range of the middle plate, and the notched area is designed to correctly align the hole in the middle plate over the holes on the top and bottom plate on each side of the increment dispensing cycle. Since there is no easy way to describe how to measure out the dimensions of this large angled notch, I have provided a scale template of all three dispenser disks plus the powder chute: part image. This image also shows the center points for the 1/8" holes that are to be drilled to hold the brass connector pin. The disks on the printed image should measure 3 inches across if scaled correctly, and could very well be something different

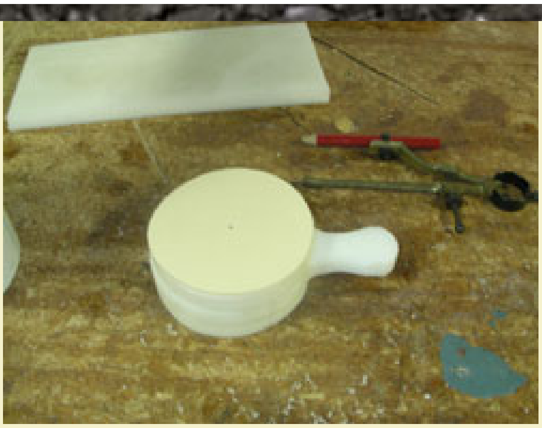

Figure 22: The three disks are fastened together using double sided carpet tape so the pieces will not slide during drilling.

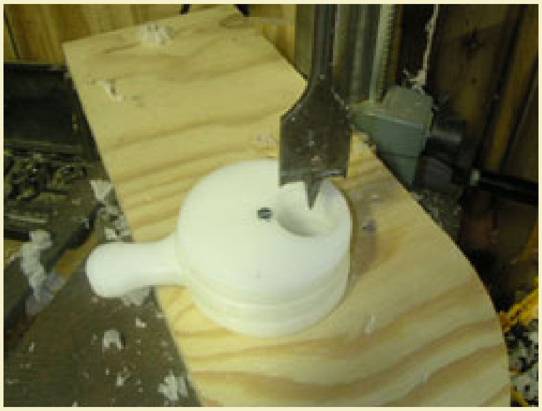

Figure 23: After the center hole is drilled, the machine screw is put in place before drilling the 1-1/8" diameter powder increment hole through all three plates.

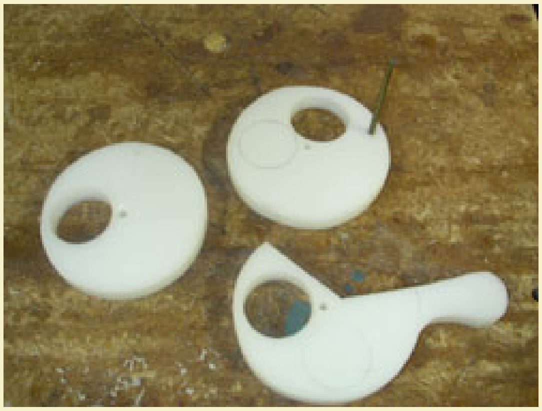

Figure 24: The completed plate set, with the special slice removed from the inner rotating plate.

depending on your printer. You may have to play around with resizing the image before printing it in order to get the scale to be accurate.

If you are successful in using my blueprints to replicate the the dispenser components, you can now assemble them by inserting the brass pin into the bottom plate, place the middle plate in position, press the top plate down over the brass pin and then connecting them all together with the central machine screw. The excess brass pin is cut off flush with the plate surface. The machine screw is fitted with a make-shift lock nut made by putting a dab of hot glue on the end of the screw and quickly threading the nut onto it. The nut is snugged down, but not hard enough to interfere with the smooth sliding operation of the middle plate. Figure 27 shows the completed powder dispenser. The hole that appears under the notched area of the middle plate is the bottom of the dispenser where powder will be dropped out, which is also the side where your lock nut should be located.

The completed dispenser is not attached to the bottom of a length of 3" I.D. PVC pipe as seen in Figure 28. A bead of hot glue is run around the edge of the top plate and then quickly pressed into the bottom of the pipe. Care must be taken not to press the dispenser in so far that the hot glue buildup around the edge interferes the operation of the dispenser lever.

The length of the PVC pipe can be whatever you find convenient, but I found the 7" long one shown here to be a bit on the small side. A pipe of this size will only hold enough powder to charge three or four drivers before you have to reload it. Something at least twice as long is recommended.

Once the powder dispenser is complete, it is fastened to the left side of the frame using pipe clamps, as seen in Figure 29. Large holes are drilled through the side of the frame so that the pipe clamps can run through it. The bottom of the dispenser is located just below the central cross bar, leaving enough room for your hand to easily access the lever. The dispenser is rotated so that the drop hole is located right against the frame, as seen in Figure 33.

An aluminum guide chute must be used to get the powder from the drop point under the dispenser to the funnel, as seen in Figure 33. This chute can easily be fashioned from a piece of aluminum flashing that is about 3-3/4" wide and 8" long, with the corners on the exit side rounded off. The coated surface of the flashing makes a smooth surface that allows the powder to flow nicely. The flashing is rolled up into a "U" shape and then twisted into a spiral as seen in Figure 31. When the twisted piece is released, it should form the chute seen in Figure 32. The corner of the chute is inserted between the powder dispenser and the frame before the pipe clamp is tightened, which will hold it securely in place once tightened.

Lastly you will need to create a lid for the powder dispenser. I cut a lid from a leftover piece of oak, as seen in Figure 30. There are no PVC fittings that I know of for plugging the inside of a tube, since the inside is irregular and incapable of forming a good seal. All PVC caps fit around the outside of the pipe, which means you would not be able

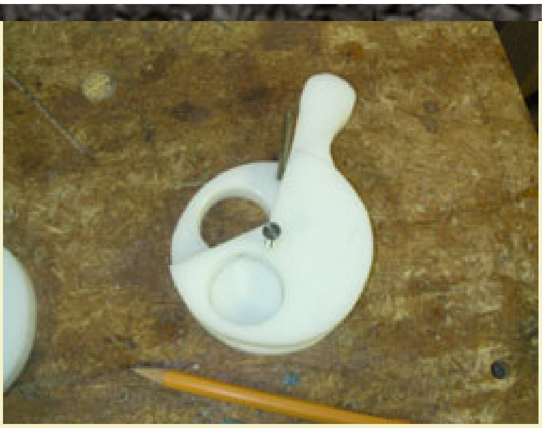

Figure 25: The brass stop pin serves as a rotation limit as well as a means to keep the bottom plate aligned with the top plate while the inner plate rotates.

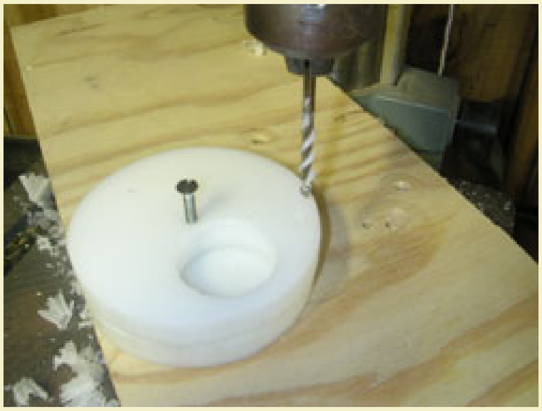

Figure 26: The top plate is placed over the bottom plate and used as a template when drilling the brass pin hole so that the two pieces will be correctly aligned.

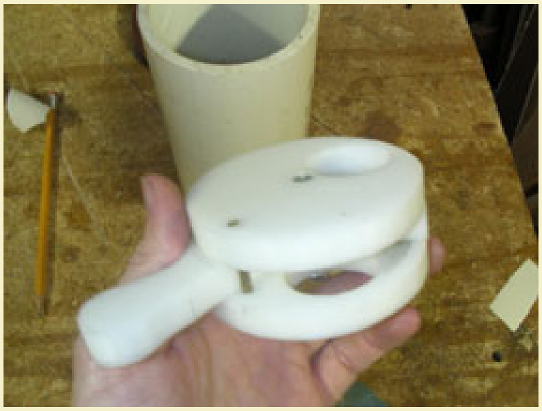

Figure 27: The completed powder increment device showing the entry hole on top and the exit hole on the bottom.

to clamp the pipe directly against the frame as seen here. Some kind of stand-off would have to be used to space the pipe out away from the frame if you wanted to use standard PVC pipe caps for the lid.

More...

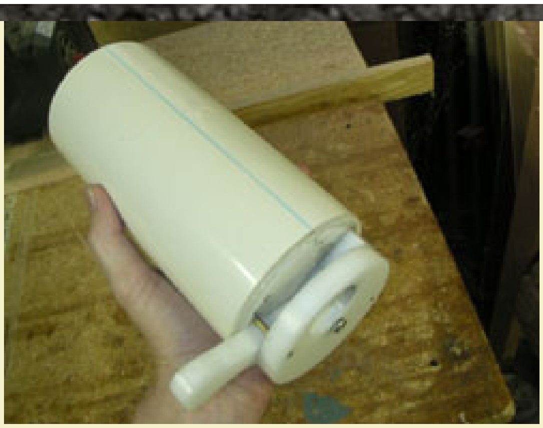

Figure 28: The powder increment device is hot glued into the bottom of a 3" I.D. PVC pipe, which will be the powder store for granulated composition during use.

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Maltese Driver Rammer...

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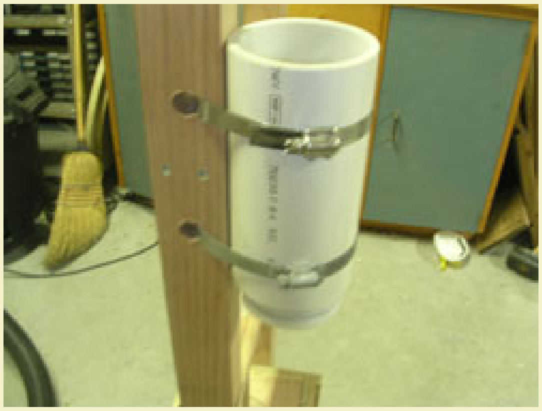

Figure 29: The powder dispenser unit is attached to the left side of the frame using pipe clamps running through holes drilled in the frame.

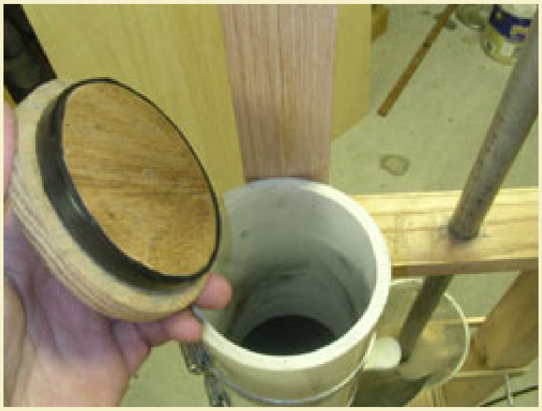

Figure 30: A wooden lid is made to close off the top of the powder store, since standard PVC caps can not be used.

Usage Notes:
When I first thought about building this type of ramming tool out of wood, my concern was that wood would be too wobbly or dimensionally unstable to keep the rammer exactly centered above the tube with such tight tolerances. However, the combination of oak and concrete has resulted in a rock solid tool that seems impervious to even Florida's extreme humidity. The rod slides easily through just the holes drilled in the wood without any need for special bearings, and as long as your tube has the correct diameter inside, the rammer will never stick and always stays aligned.

The first step to getting your driver production up and running is to produce or obtain the correct size driver tube. Because this machine requires very specific inside and outside diameters on the tube being loaded, your choices for tubes are more limited. If you don't like rolling your own tubes, you should locate a reliable supplier for the tube you need before building the rammer, then change the rammer diameter and funnel plate hole to match your tubes. The length of the tube is not much of an issue, since you can re-pin the funnel plate to one or more heights to match the tubes you plan to use.

Being the control freak that I am, I prefer to roll my own tubes. I have had bad luck with all but the most expensive virgin kraft tubes when making high powered end burning drivers, but my home made manila paper tubes never fail me. Rolling your own tubes gives you exact control over both the inside and outside diameters of your tubes, and also insures that your tubes will not split from the excessive ramming force that this tool is capable of producing. For example, about five whacks while loading the clay plug in a Skylighter TU1062 recycled kraft tube will bulge the case to the point of tearing. Even if this tube survived the loading process, it will burst under the pressure when fired if built according to the specs below. With hand rolled manila tubes, there is no bulging and no tube blowout problems. There is a tendency for plugs to blow out of manila tubes more easily than recycled kraft tubes however, which is a problem common to any rock-hard tube since there is no bulging of the case wall to help lock in the plug.

Making the Driver Tubes:
To roll your own tubes, you first need to produce a rolling rod that will result in a very slightly oversized tube I.D. This is done by taking a leftover segment of your 3/4" diameter ram rod about 9 inches long and wrapping three turns of 2" wide packing tape around it at side-by-side intervals until the entire length of the rod is covered. There can be slight spacing between the bands of tape, but don't let turns from one band overlap the previous band or you will be creating a high

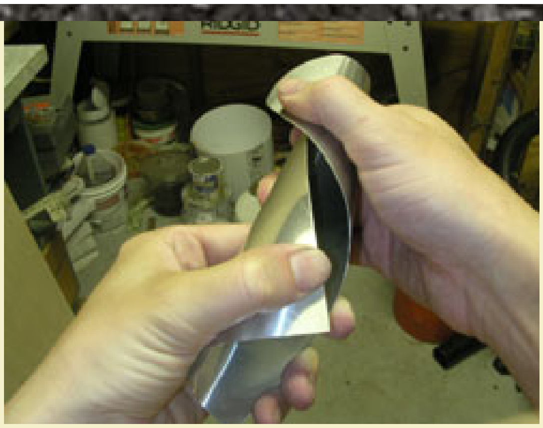

Figure 31: Twisting a sheet of aluminum flashing to produce the powder chute.

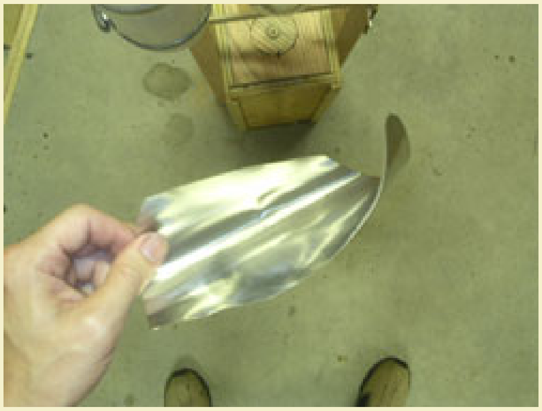

Figure 32: The completed powder chute that will carry powder from the dispenser to the funnel.

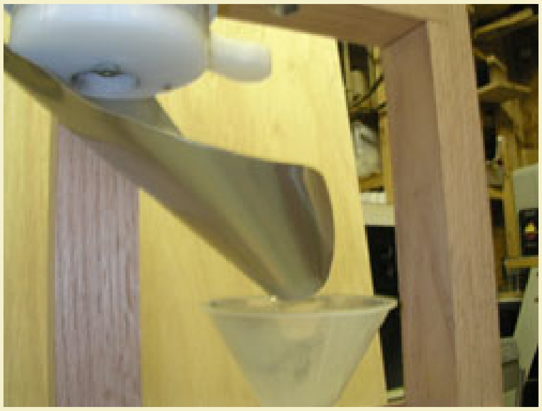

Figure 33: Powder chute is pinned between the powder dispenser and the frame.

spot on the rod. Building up the rod diameter like this allows you to fine tune your tube I.D.s until you get the size that works best. If your tube shrinks too much with three turns of tape, try four. You want your ram rod to easily drop into the tube without any binding at all. Once you find the magic number you can always measure the final diameter and have a special rod turned down on a lathe if you don't like the look of your taped up rod. The tape will also likely come off over time and need to be re-applied, so a machined rod would be nice to have for the long run.

The case is rolled from two strips of 14-1/2" long legal size manila file folder paper plus a third strip that is 11" long, with a final two turns of 30lb recycled kraft to keep the tube from unraveling after it is rolled. The strips are rolled one at a time, using a mixture of 50/50 white glue and water brushed onto one side of the paper before it is rolled. This tube will dry to have a 1-1/8" outside diameter that fits snugly into the bottom hole on the funnel plate. Note that it is important not to let the tube telescope while you are rolling it, as this will create a tube that is too long to fit into the loading fixture. It will save you work later if you just unroll a strip that is starting to get out of line and adjust the alignment so that it rolls straight. Tubes that do turn out too long to allow the funnel plate fixture to lock down can be quickly shortened using a fixed belt sander to trim down the ends.

Loading the Clay Plug:

For a driver of this size, it is necessary for the inside surface of the clay plug to have a curved surface in order to avoid problems with burn-through just above the nozzle. To understand why this is, refer to the clay nozzle article published here. What this means is that you can't use the flat-ended powder loading rammer to ram your clay plug. One option is to hand ram your clay plugs using a rounded off ramming drift and then use the loading tool only for ramming the fuel. However, since the ramming tool produces more force than hand ramming is capable of, a clay plug produced on the ramming tool can endure higher pressures before blowing out and thus makes your drivers more reliable. What I opted to do was make a second ramming rod that has a rounded off end to produce the desired curvature on the plug. This is a duplicate of the flat ended rammer, complete with it's own lead soda can weight at the top. The rammers are easily interchanged by pulling them out the top of the frame, so you can use the plug rammer to ram the plugs in a large batch of tubes, then swap out to the fuel charging rammer to finish loading each driver.

The plug formula I prefer is ground up floor tiles or flower pots screened to 25-40 mesh mixed with bentonite in a ratio of 1:3. The bentonite can optionally be treated with 5% wax for moisture proofing if you are worried about the clay absorbing humidity in the air and shrinking.

More...

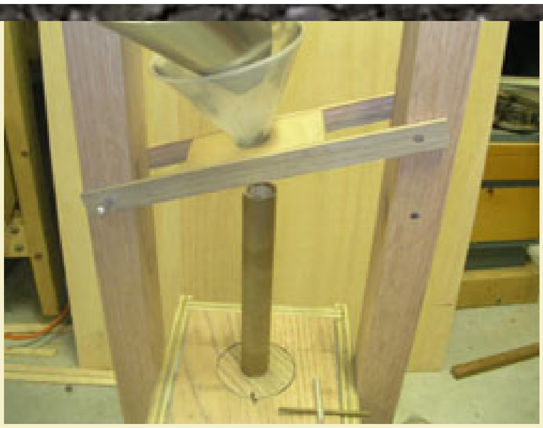

Figure 34: A tube being loaded into the completed driver rammer.

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Maltese Driver Rammer...

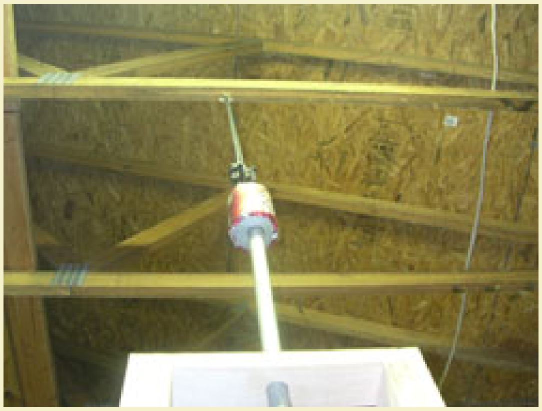

Figure 35: Using bungee cords to suspend the rammer from above.

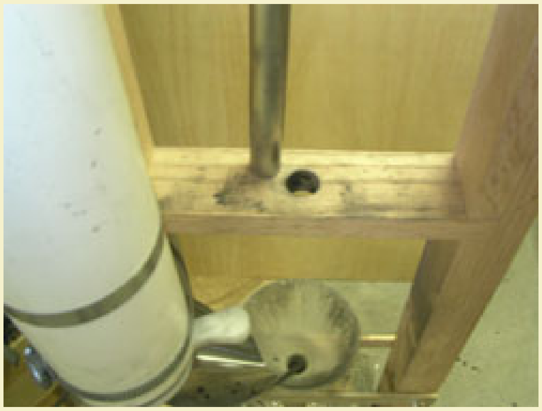

Figure 36: Resting the rammer on the center support while loading driver tubes.

Loading the Fuel:
A good strong driver capable of 500g thrust when using a 3/16" diameter choke hole can be produced using the formula given here. This should be ball milled for two hours, then dampened 20% and granulated through a window screen. This granulation step is crucial, as you can not use the powder dispenser with ungranulated powder or it may jam up. Ungranulated powder will also result in a huge dust problem, far worse than hand ramming will produce. In fact, even granulated powder can cause a dust problem with this type of driver loading tool, since the ram rod falling into the case forces the air to rush past the sides of the rod and carry any loose dust with it. The trick to minimizing the dust problem is to dissolve 1% dextrin into your water when dampening the composition. This dextrin will add some strength to the dried granules so they do not crumble so easily. However, the amount of dextrin used must be minimized to no more than 1%, otherwise you will get granules that are too hard to crush easily when rammed. These uncrushed granules will cause hot spots at your increment boundaries that blow bursts of high pressure as the driver burns. Assuming your choke can even handle these pressure spikes without blowing out, your drivers will sputter with loud bursts each time it hits an increment barrier.

The loading procedure is pretty simple and fast. When loading a driver, the ram rod is pulled up out of the middle support bar and rested on top to hold it out of the way as seen in Figure 36. Once your driver is inserted and locked down, the rammer is reinserted and dropped down into the funnel. Now you simply flip the powder increment lever and let the 1/2 table spoon charge fall into the funnel. The ram rod is lifted out of the funnel so that the charge can fall in, then it is slammed down about 6 to 8 times until the charge is fully compacted. Grab the ram rod just above the middle support bar and lift it so that the rammer comes all the way out of the tube, then throw it down into the tube to give it a good whack.

The charge/ram sequence is repeated about 14 times or until such time that the powder increment can be seen sitting in the funnel throat instead of disappearing into the tube. After ramming this last increment, a final 1/2 table spoon of straight bentonite is used to plug the driver. One nice thing about this kind of loading device is that it lets you fill a tube right up to the top, with the final clay plug being flush with the end of the tube.

Performance Notes:
In my timed tests, which involved loading the plug, comp and end plug into a set of 10 drivers one after the other, the average load time for producing a finished driver is about 3.5 minutes. Of that time, 1

minute is required for ramming the end plug while 2.5 minutes is required to load the 14 fuel increments plus the end plug. When producing the same size driver by the traditional hand ramming method it takes me about 6 minutes, so this machine almost cuts the time in half.

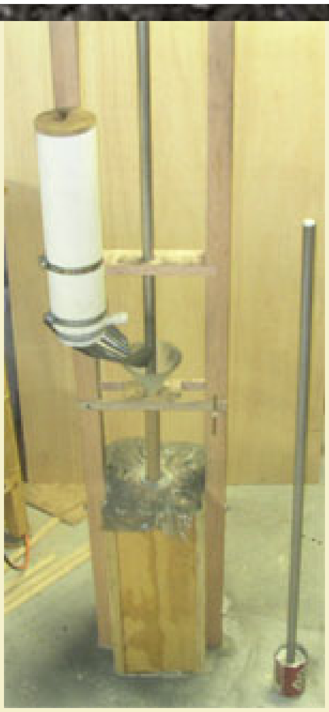

Figure 37: An extended powder store handles about 12 drivers. Note the additional rammer rod for clay plugs.

While this machine saves you considerable time and produces a better quality driver than hand ramming, it does not remove any of the physical labor from the process. In fact, since you are actually doing the same amount of work in half the time, using this machine to do more than a few drivers consecutively can be rather exhausting on your arms. While 10 pounds might not seem like much to lift one time, consider that you have to lift it 130 times to produce one driver! This thing could literally qualify as the first pyrotechnic tool that doubles as an effective exercise machine.

Toni's original machine attempted to get around this arm fatigue problem by suspending the rammer from a spring or bungee cord, such that the operator spends more energy thrusting the bar down into the driver and less energy pulling it back out. A similar setup can be seen in Figure 35, with the bungee looping around a hook in the ceiling joists. The problem I find with this system is that the pull from the spring is seldom exerted exactly in line with the rammer, which causes the rammer to rub against the guide holes. This rubbing causes extra friction that seems to about equal the amount of work you are trying to save with the spring, so I tend not to use it. However, if you don't prefer the bicep workout feature of this tool, I suggest you put the extra effort into getting the overhead spring to function correctly.

All in all, I find this tool a useful edition to my collection. I've always dreaded hand ramming the 18 or so drivers that it takes to make a single mid sized girandola, and now I can be done with that chore in just one hour. Considering that the Maltese pyro clubs use the same design to hammer out several thousand drivers per year, there is probably no faster way of doing it without resorting to more advanced machinery.

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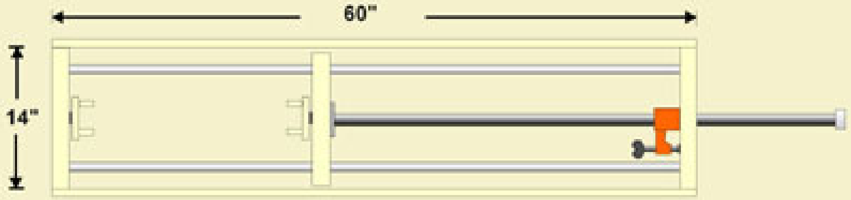
Tool Tip... Page 1

Multi-Break Shell Press

by **Kyle Kepley**



Introduction:
The press described in this article is designed to facilitate the assembly and spiking of large multi-break shells. The shell construction technique requires that each break be completed and spiked individually in order to be used with this press. It is ideally suited for the construction of Maltese shells, which use this modular construction method.

This press must be used in conjunction with the Maltese shell roller described in the June edition. While the shell roller is a tool commonly used in Malta, this particular press is my own design. I do believe some Maltese builders use some kind of press to assemble their breaks, but I don't know the details of their designs. This one is very simple and works well as an accessory to the shell rolling tool.

The purpose of this device is to compress all the breaks together while still allowing them to be rotated. The amount of compression force generated is much greater than can be achieved by attaching one break at a time using spiking twine.

The fact that the shells can still be rotated while under compression makes the task of filling in between the breaks with newspaper much easier, since there is no spiking twine to get in the way. After the gaps have been rammed with pasted newspaper and compressed as far as possible, they will expand very little after the vice is removed. This allows the vertical twine that secures the breaks to be applied around all the breaks as they rest on the roller. The entire shell is assembled and spiked together without ever having to lift it off the rollers!

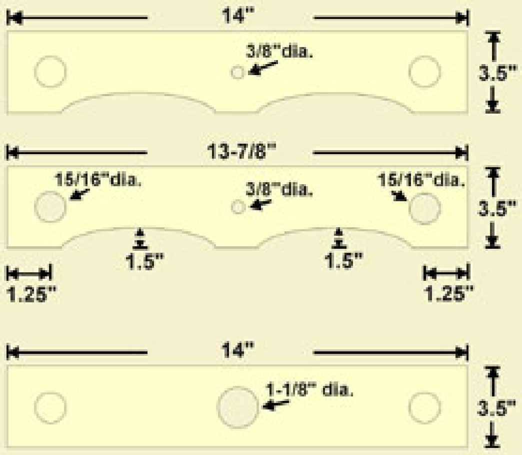


Figure 1: Dimensions of 2x4 frame pieces.

Materials:
- (2) 60" long 1x4s
- (2) 14" long 2x4s
- (1) 13-1/8" long 2x4
- (2) 58-1/2" long 1" conduit
- (1) 48" long 3/4" black plumbing pipe
- (1) 3/4" pipe flange
- (1) 3/4" pipe clamp w/screw on sliding jaw
- (1) 3/4" pipe end cap
- (8) 2" long 1/4" lag screws
- (8) 1/4" washers
- (2) 2-1/2" long 3/8" bolts
- (2) 3/8" ball bearings
- (2) 3/8" washers
- (2) 3/8" lock nuts
- (8) 2" long 3/4" dowel rod

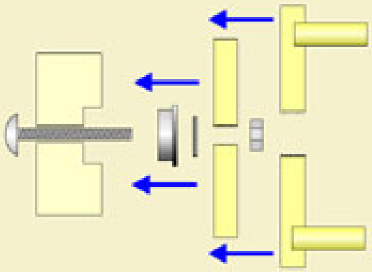


Figure 2: Assembling the rotary heads.

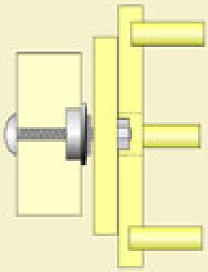


Figure 3: Rotary unit mounted on stationary vice jaw.

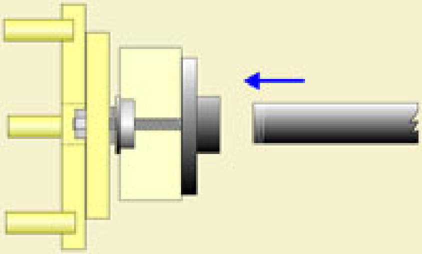


Figure 4: Threading the 3/4" black plumbing pipe into the flange mounted on the movable vice jaw.

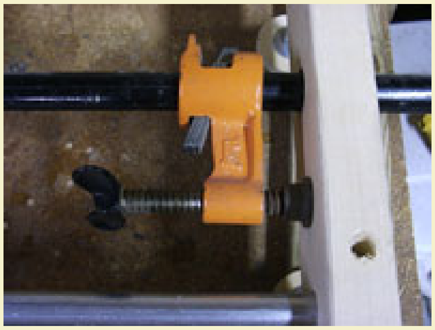


Figure 5: The reversible pipe clamp provides the force.

- (2) 4" dia disks of 5/8" plywood
- (2) 5-1/2" dia disks of 5/8" plywood

Assembly:
Start by preparing the pieces shown in Figure 1. The 15/16" diameter holes go all the way through the center piece, but are countersunk 3/4" deep in the two end pieces, which is where the 1" conduit will fit into. The round cutout area on the bottom of the first two pieces, which are the vice jaws, do not have to be any specific shape as long as they are 1-1/5" deep and have enough curve so that they do not hit the roller bars that the vice will sit on. The center hole on the first two pieces, which is 3/8" diameter, will also need a countersink large enough to seat the bearing shown in Figure 2. This hole will vary depending on the size of your bearings, but it should be drilled first before making the 3/8" hole.

Next you should attach the bearing assembly to the two jaws, as seen in Figure 2. Hammer the bolt through the back side hard enough so that it will not rotate when you tighten the lock nut on the other side of the 4" wooden disk. The second disk shown in Figure 2, with the 3/4" dowel rod fingers glued into it, is not part of the assembly. It is an interchangeable piece that just fits tightly over the lock nut. This piece will need to match the diameter of the shell you will be clamping, such as 5-1/2" for a six, 7-1/2" for an eight etc.

The inner sliding jaw, which is the second piece from the top in Figure 1, needs to have a 3/4" flange mount for the pipe clamp bar to screw into. This is screwed onto the back of the jaw after the rotary assembly has been attached, as seen in Figure 4.

Now you are ready to assemble all the pieces, using the two five foot long 1x4s to make the sides. Each side piece is screwed onto the ends of the 2x4s using the 2" lag screws with washers under them. Do both sides of one end, then insert the two pieces of conduit, slide the movable jaw over them, then attach the remaining side of the frame.

The type of pipe clamp required for this project is the reversible kind where the screw mechanism is located on the sliding piece rather than fixed to the end of the pipe. Both kinds are sold in kits that don't include the bar, so be sure to get the right kind. Figure 5 shows how the clamp piece is positioned at the back of the press when applying pressure to a shell.

The four foot piece of 3/4" pipe should easily fit through the hole in the back, through the clamping mechanism shown in Figure 5, and screw into the flange mount on the movable vice jaw.

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Multi-Break Shell Press...

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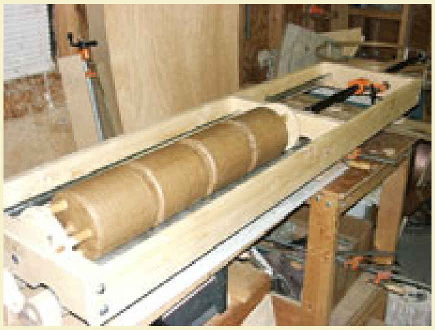
Figure 6: Four 6" shells being compressed together.

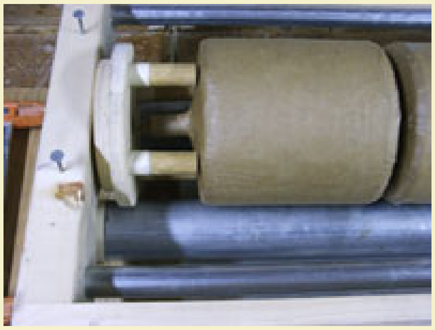
Figure 7: Fingers are long enough to allow room for spolette.

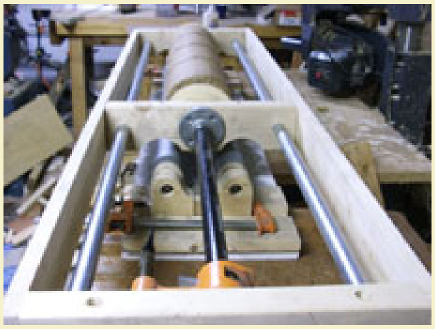
Figure 8: End view of press frame sitting over the roller.

Application:

When using this press, you will first need to insert the correct set of finger jaws onto each end. These are simply disks that match the shell diameter and have four equally spaced dowel rods glued into holes along the periphery. Figure 7 shows a close-up of a jaw, note how the fingers are long enough to make room for the spolette.

The rotary disks actually ride on the shell rolling bars that are part of a separate jig. It will be necessary to adjust the feet at the back end of the press frame so that the heavy bar clamp does not cause it to tilt when no shell is present.

The individual beaks are first stacked upside down, then placed onto the rollers. The adjustable jaw is brought up against the bottom of the shell, and the screw on the clamp mechanism is screwed all the way out to allow for maximum travel. The clamp ratchet is then slid all the way against the wood. Now you simply turn the clamp screw and press the shells together. Figure 8 shows an end view of the press in action.

Since the shell can still freely rotate even when under pressure, it is very easy to ram the pasted newspaper between the breaks to fill the remaining gaps. Full length strips of crumpled paper are fed into the gap and rammed with a thin stick while the shell is rolled, as seen in figure 9. While this step is traditionally done after the shells have been strung together, using this method avoids the hassles of trying to work the paper in between the many strands of twine that get in the way.

It is actually possible to string the shell while it is still between the clamp jaws, which is done by winding the string onto a shuttle and passing it between the fingers at each end of the shell. However, since the shell will not uncompress any noticeable amount when the clamp is removed, it is much easier to remove the press and apply the vertical spiking without any obstructions.

The shell rolling jig and this press combine to make the final assembly of large multi-break shells one of the easiest parts of the overall process!

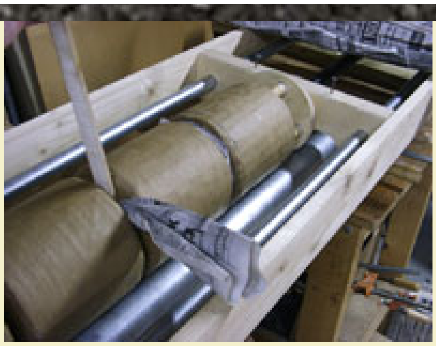
Figure 9: Paper wadding is rammed in with ease.

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Design Notes...

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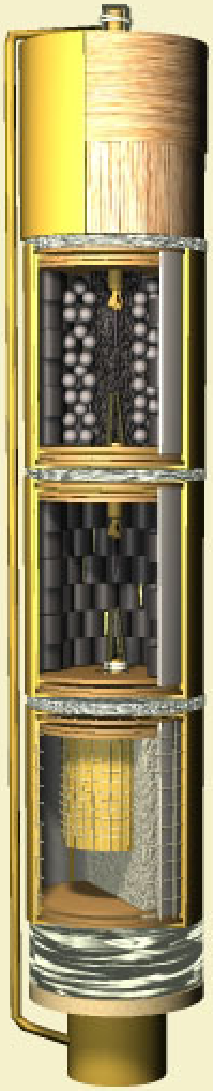
Maltese Multi-break Shells

by Kyle Kepley



Introduction:

In the Fall of 2001, the Florida Pyrotechnics Arts Guild, in a partnership with the Texas FireAnts guild, brought two expert Maltese shell builders to America for a few weeks in hopes of getting a glimpse at the techniques involved in building the large multi-break shells that Malta is famous for. The idea was motivated by the successful exchange of knowledge achieved by the Crackerjacks club the previous year, where Toni Busutilli brought his intricate irdieden craft to share with Americans. Little did we know that this venture would end up being one of the best investments our guilds have ever made!

Until recent years, it has been customary for the American pyrotechnist wishing to learn more about Maltese methods of fireworks construction to make the pilgrimage to Malta to observe them making and displaying their craft. This has resulted in bits and pieces of various aspects of Maltese shell construction to be adopted by a few American shell builders over the years, although not much has been published on these methods. By bringing a few shell builders to America for a personal hands-on demonstration of building the shells from start to finish, a more complete account of basic Maltese shell construction was filmed and documented.

Fred and Lee Partin of the Florida guild worked with Bill Kimbrough of the Texas guild to bring over two well known shell builders from Malta-- Bennie Farrugia and Paul Schembri. To appreciate the sacrifice these two men made for the sake of educating us about their craft, consider that they agreed to fly overseas during the climate of insecurity immediately following the terrorist attacks of September 11. Their family made both of them sign a Last Will and Testament, with instructions to a banker to assist the family if they did not return. They then set off on a month long journey to a foreign land to meet with people they knew nothing about. This dedication to the art speaks volumes about Bennie and Paul, and we owe them a debt of gratitude for going through all this trouble to share their knowledge with us.

I was among those lucky enough to follow Bennie and Paul around for the majority of their stay in Florida, taking plenty of video and observing the whole process in person. My efforts will now be focused on getting this information out to Passfire readers in a series of articles that will appear on this website. This month will examine the basic structure of Maltese multi-break shells in general. Future articles will focus in more detail on step-by-step procedures for building specific shells, along with any tools or techniques that are required. While certain trade secrets will not be disclosed at the request of Bennie and Paul, it must be noted that these secrets are not necessary for insuring both the safety and functionality of building successful Maltese shells.

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Maltese Multi-break Shells...

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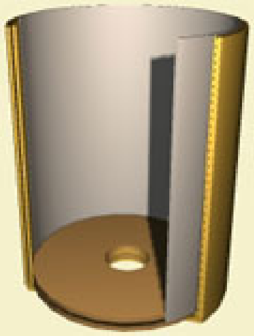

Figure 1: Pasted paper cans made from two turns of poster board and recycled kraft.

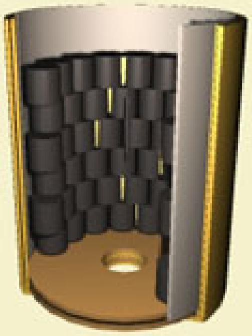

Figure 2: Comets held tightly in rings with wooden wedges.

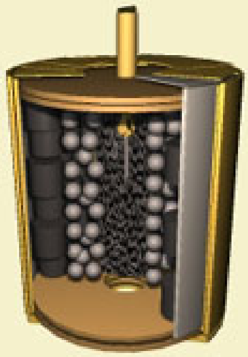

Figure 3: A fully loaded shell with 1/4" round stars and pulverone break charge.

The Breaks:

Construction of a Maltese shell begins by rolling all the cans for each break and the bottom shot required in the final shell. These cans are faster to produce and require less paper than the equivalent case of an Italian style shell. Regardless of what size shell is being produced, the cans consist of only two turns of poster board along with two turns of a 40 weight kraft paper, which can even be a cheap recycled variety! The strength is achieved by pasting the paper on one side when it is rolled, leaving a rigid can when dry. The kraft paper is pasted on one side, then the poster board strip is placed on top such that only half its length overlaps the kraft strip. The poster board is then pasted over half its length so that it will not stick to the former. The two strips are then rolled up together.

With the exception of the bottom shot cans, all cans will contain a hole in the bottom to accept the fuse from the break it will rest on top of. The bottom shot can will contain a hole exactly equal to the outside diameter of the spolettes being used. Two disks are required to make the bottoms of each can, as seen in Figure 1.

The traditional paste used for making Maltese shells is made from boiled water and flour. Upon cooling, a small amount of paris green is added to the paste in order to prevent bugs from devouring the cans in storage. The expense of paris green in recent times has led to the substitution of copper oxychloride for this purpose. The paste is typically prepared the day before it is to be used.

The disks are held in place by slicing the edges of the can with a sharp knife while still wet with paste, then pleating down the tabs over the disk while it is still on the former. The first disk is held down by only pleating the poster board layers, while the second disk is placed on top and pleated over with the remaining kraft paper tabs. These cans are fast to construct due to the minimal pleating required, especially when compared to larger sized shells constructed in the traditional Italian method.

After the cans are dried, which only takes a few days, they are loaded with rings of comet stars. Since potassium perchlorate costs about twice as much as chlorate in Malta, and since shells of this size consume a considerable weight in stars, the Maltese use all chlorate formulas for their color stars. These stars are bound with a solution containing dissolved gum arabic, which is a superior binder to dextrin and produces a stronger star that is less likely to fragment during loading and also when the shell breaks. A meal prime slurry, which also contains gum arabic as the binder, is used to prime all the stars (including the chlorate stars). Rather than ram sawdust between the comets to lock them tightly into rings, simple wooden wedges are chopped from a block and wedged into place as needed. Figure 2 shows a typical can with the comets and wedges in place.

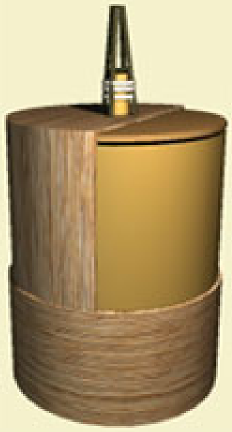

Figure 4: Solid spiking with single ply jute twine.

Due to the sensitivity of chlorate stars to friction, great care must be taken when loading the stars and inserting the wedges. One secret to getting tight rings without using force is to load the stars the day after the cans are pasted so that paper is still damp. The stars are loaded snugly, but not wedged forcefully. When the can fully dries, it will shrink around the stars and compress them into tight rings.

Figure 3 shows an arrangement of 1/4" round stars around a central core of break charge, which would be a common configuration for a six inch break. Surprisingly, the Maltese break all their shells with pulverone made from ball milled meal powder. The pulverone used for break should pass a 1/4" hardware screen while sitting on an 1/8" screen. Everything that passes the 1/8" screen is put aside for use as lift. Thus, absolutely no commercial black powder is required for building these shells! Given the rising price of Goex in America, this feature alone makes the Maltese method worth adopting.

At this point you have a loaded shell made from a few turns of cheap recycled paper, poster board and a rough powder break charge. You are probably thinking "how is this thing ever going to have enough containment to break correctly, not to mention survive getting out of the gun?" Well, now comes the hard part.

The Maltese spiking method requires a continuous layer of a special 1-ply jute twine, both in the vertical direction and horizontally. The shell is strung with four strands at a time to help the process go faster, but it still takes longer than Italian style spiking. After applying the verticals, you should not be able to see any of the shell between the strings. The same is true of the horizontal spiking, giving a finished shell that looks like a ball of twine! Once complete, a final paste wrap of two turns 30 lb recycled kraft is used to fireproof each break.

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The Bottom Shot:

The bottom shot consists of a smaller salute nested inside a larger can, with the empty space being filled with sand. Since most Malta shells are of a large caliber, the use of smaller insert salutes in the bottom shot is necessary to save materials and create a safer shell. Again, the high cost potassium perchlorate results in the use of chlorate based flash powder in all Maltese bottom shots.

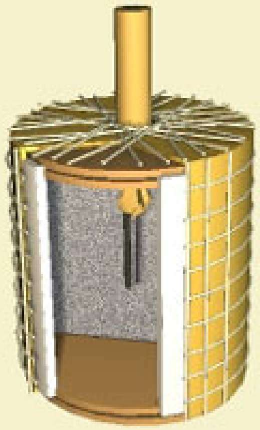

Figure 5: Inner salute casing made just like a shell.

The salute can is rolled just like the cans used for the main breaks, except only two disks are used in each end and four turns of poster board are used instead of just two. An additional four turns of 30 lb fire proofing paper is pasted around the salute after it is loaded. The salute is then spiked using four strands of cotton twine to create a flat band of twine that intersects in small squares about 1/4" on each side. Figure 5 shows the finished salute (parallel spiking strands not shown). After spiking, the string is saturated with a mixture of white glue and paste in a 50/50 ratio. This is applied using a paint brush, as the mixture is rather thin.

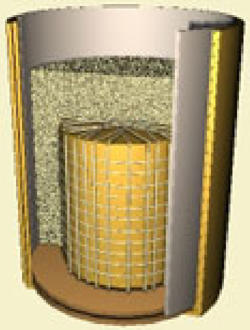

Figure 6: Constructing the bottom shot upside down.

When the bottom shot can is rolled, the disks are fitted with holes that match the outside diameter of the spolette on the inner salute. The inner salute is inserted through the bottom of the can in an upside down position, then sand is packed around it and slightly above it.

It is said that the sand helps weigh the shell correctly in order to prevent undesirable rotation when the shell leaves the gun. I believe that the sand is also easier to load than sawdust, is cheaper, does not compress and provides more resistance when the salute breaks. These characteristics are all desirable and not produced with the use of sawdust. Due to the way these shells are lifted, the increase in shell weight through the use of sand does not pose any undesirable problems. As you will see, surprisingly little lift is required to get these large shells to the proper height.

Once the sand is loaded and packed around the salute, two disks are inserted, pleated over, then finished with a third disk on each end. The shell is now spiked with a single strand of cotton twine in the standard Italian method.

The finished bottom shot is fireproofed with two turns of 30-40 kraft just like all the other breaks, as seen in Figure 7.

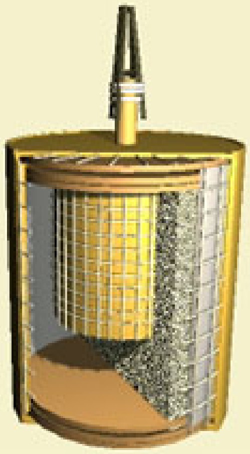

Figure 7: Finished bottom shot

Each break will be fully completed as a separate shell, then assembled by simply inserting the spolette of one into the bottom of another and stringing them together. Using a special shell press that will be described in a future article, the breaks may be squished together all at once and held with a single set of strings. Pieces of lightly pasted newspaper are rammed into the gaps between each break, which helps protect the spolette joints from accidental loaded with sand, spiked and pasted.

ignition and also serves to cushion the shells during lift.

Once all the breaks are fastened together, the entire shell is pasted in with just two turns of 60 lb recycled kraft. Note that the Maltese do not break the paper when pasting both the cans and the outer wrap. The paste is simply spread onto one side with a brush or the hands. When pasting the outer wrap, both sides of the paper get pasted.

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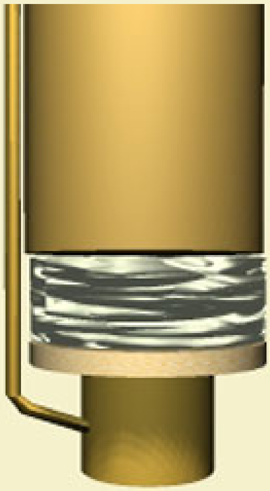

Figure 8: Shell, paper wadding, wooden disk and lift charge.

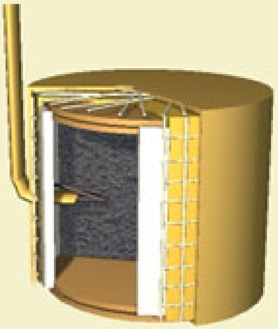

Figure 9: Lift charge constructed like a 4" shell.

The Lift:

The lift mechanism is perhaps the most ingenious aspect of Maltese shell construction. Not only does it allow rough powder to be used as the lift charge, but considerably less lift powder is required for the larger shells than when lifting with black powder. This is because almost all the gas generated by the lift charge is harnessed to lift the shell, rather than allowing some lift gas to escape as "blow-by" traveling alongside the gap between the shell and the mortar wall.

The lift powder used is simple rough powder made from ball milled meal such that it passes a 1/8" hardware screen. The powder is packed into a small 4" shell as seen in Figure 9. This lift can is constructed in the same way as all the other cans, except with two end disks instead of three. The can is then closed and spiked with one strand of cotton twine and then pasted in. This essentially creates a black powder salute, also known as a maroon. The amount of rough powder used for some common shells are shown below:

SHELL TYPE	WEIGHT	LIFT USED
4" 3-break w/bottom shot	6 lbs	180 g
4" 8-break	10 lbs	225 g
6" 3-break w/bottom shot	20 lbs	200 g
7" 3-break w/bottom shot	40 lbs	350 g
8" 3-break w/bottom shot	70 lbs	600 g

Note that these lift recommendations are for traditional Maltese shells, which have shorter timing between breaks than what is common in America. The Maltese also break their shells at a lower altitude than the commercial shells we are used to seeing and making. This results in a rapid succession of breaks that occur lower on the horizon. The lift quantities given here will have to be adjusted if higher altitudes with more drawn out timing is desired. When using this lift system there does not seem to be any rule of thumb like the "ounce per pound" rule for using black powder, so some experimentation is inevitable.

The lift can is placed under a disk made of plywood that is equal to the outside diameter of the shell to be lifted. A thick wadding of paper, known as a "sabot," is placed between the disk and the shell, and the whole assembly is held down against the bottom of the shell with either twine or tape (see Figure 8).

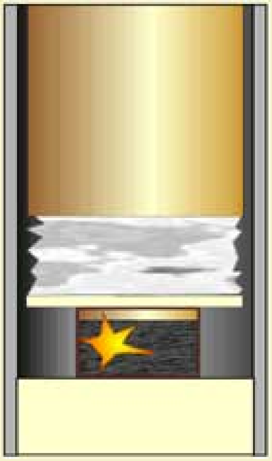

Figure 10: Pressure builds in lift charge case.

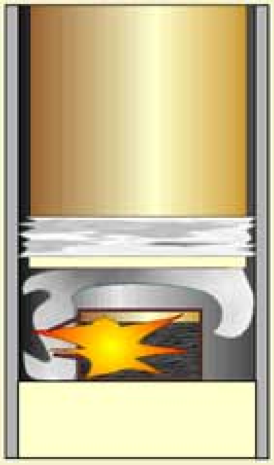

Figure 11: Case bursts, sending pressure impulse that forces wood disk upward.

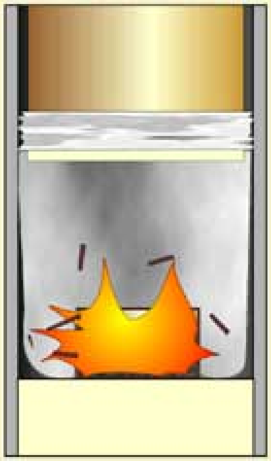

Figure 12: Wood disk compresses sabot, trapping all lift gas and sending shell

upwards.

The lift sequence is shown in Figures 10 through 12. The lift can contains the pressure at first, then releases an impulse of pressure when the side bursts out. This impulse forces the wooden disk upwards and crushes the paper sabot, as seen in Figure 11. The paper wadding expands outward to form a seal around the edge of the disk, thus preventing any blow-by gasses from escaping up around the sides of the shell. This allows the full volume of gasses generated by the still burning rough powder to be used for lift. The rough powder continues to burn as the shell accelerates out of the mortar, as illustrated in Figure 12.

The sabot also provides a cushioning effect between the pressure impulse and the shell, which helps reduce stress that may otherwise rupture large shells constructed with thin walls such as these. Imagine if you took two large shells and laid them out flat on the ground, one with just a wooden disk at the end and the other with the paper cushion and then the wooden disk. Now think of the stress that would be caused if you took a large sledge hammer and struck the wood disk of both shells. The shell without the padding would likely suffer damage on impact, while the cushion of the other shell would absorb most of the force.

Although this method of lifting shells does require considerably more work than simply bagging the lift under the shell, it has the advantage of creating much less stress on the shell when fired (not to mention avoiding the use of expensive black powder). While this method would be overkill on smaller shells under a few pounds, it is ideal for heavy shells and especially long multi-break shells.

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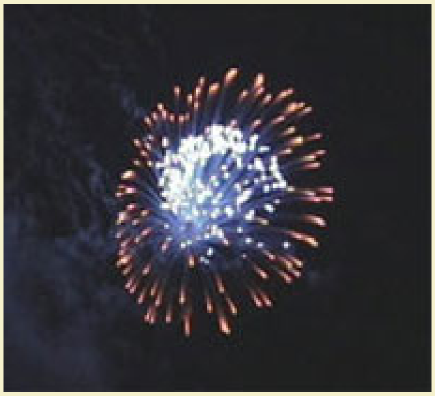

Figure 13: Charcoal comets with AP blue inner pistil.

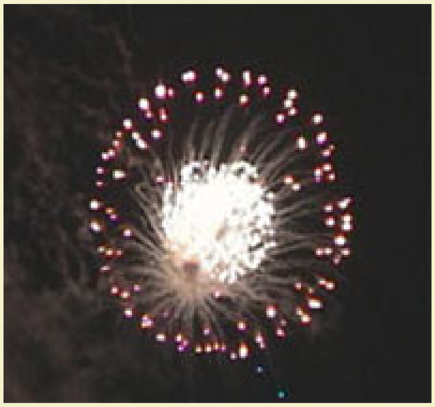

Figure 14: KP red comets with yellow pistil.

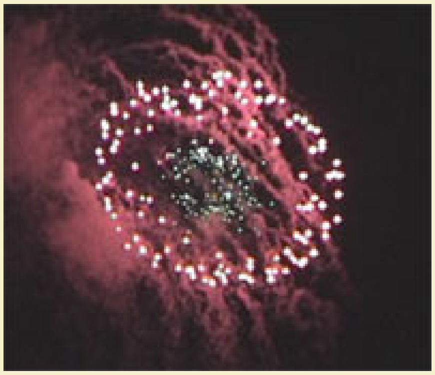

Figure 15: Maltese chlorate red with green pistil.

The Performance:

The series of pictures in Figures 13 through 16 show the types of breaks obtained from the Maltese shells described in this article. These shells were fired in April of 2002 at the FPAG Founders Festival in Florida and represent some of the first attempts to duplicate the shells Bennie and Paul showed us how to make.

The breaks shown here are at the optimal point of view, which is an end-view of the shell when it bursts. The shells produce very round outer rings of comets with a dense cluster of round stars at the center. The rings spread quite far in the plane perpendicular to the length of the shell, but spread very little in the other direction. This type of break, sometimes called a "pancake" break, results when a canister is made equally strong in all directions. As mathematically demonstrated by L.A. Jackson in the Reactions section of Pyrotechnica XVI, it can be shown that "in relatively thin walled cylinders under pressure, the circumferential or hoop stress induced in the walls is twice that of the longitudinal stress (in the direction of the central axis)."

Since there is not much spread in the direction of the shells central axis, the breaks will look flat if viewed on edge just as a ring shell would. However, they look quite spectacular when the angle of the shell axis to the viewer is at least 30 degrees or more.

Figure 13 and 14 are from a six inch three break shell made by myself. I did not opt to use the chlorate formulas given by Bennie and Paul, as I am not comfortable with priming chlorate stars with meal powder as it is done in Malta. This resulted in longer burning stars, yet the rings held their shape without sagging for the entire duration.

Figure 15 and 16 show an exact replica of a six inch 3-break Maltese shell built by Mitch Piatt. Note the brighter colors of the chlorate stars compared with the perchlorate stars in Figure 14. While the color tone of the KP red was in fact deeper than the chlorate stars in real life, the lower light output caused the transition to video to lose much of the red color.

These basic six inch multi-break shells are both cheaper and easier to produce than the same shell made using the Italian methods. As can be seen here, the breaks obtained are unique and quite pleasing to the eye.

As the information on Maltese shell building trickles into the hands of American pyro hobbyists, it will be exciting to see these shells appearing in club shoots and competitions across the country.

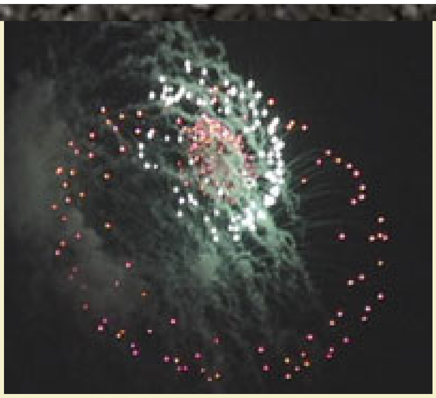

Figure 16: Maltese chlorate green comets with red pistil.

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Tool Tip...

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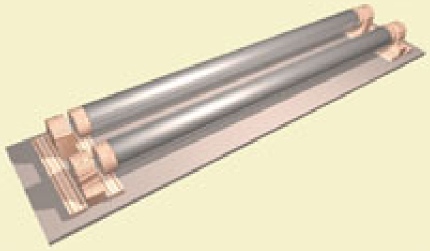
Maltese Shell Roller



Introduction:
Large multi-break shells frequently weigh over 30 lbs, and some large shells can weigh as much as 100 lbs. Such heavy shells can become quite difficult to work with during construction, especially during the spiking and assembly stages. When working with smaller shells, applying the horizontal spiking by holding the shell and rotating it is a manageable task, but this method is often unworkable with larger shells.

Maltese shell builders frequently use a roller device similar to the one pictured above in order to support the shell while allowing it to be spun around it's vertical axis. The roller bars also help to keep multi-break shells in alignment during the spiking process. The roller described here is rugged enough to handle shells weighing over 100 lbs, with an adjustable roller to allow a wide range of shell sizes to fit the roller.

Materials:

- (1) 1x4 ft laminated shelving board
- (2) 3 ft long 2" dia. galvanized conduit
- (4) 10" long 1x2s
- (4) 4" long 2x4s
- (1) 10" long 2.25" dia wood round stock
- (2) 1" long 3/8" dowel rod
- (4) 3/8" ball bearings
- (4) 3-1/2" long 3/8" bolts
- (8) 3/8" lock nuts
- (2) 2" long 1/4" lag screws
- (2) 1/4" washers
- (8) 1-1/4" long #8 wood screws

Tools:

- Drill press
- Wood lathe
- Portable drill
- Hacksaw or horizontal bandsaw
- Vertical bandsaw or jigsaw
- Hack saw
- Wood Saw (hand or power)
- 1-1/8" spade bit
- 3/4" spade bit

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Maltese Shell Roller...

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Construction:
The basic concept of this tool is such that each builder is likely to construct his own version depending on what tools and materials are available. While PVC conduit may be used for the roller bars, this will limit the amount of weight the roller can handle before the rollers bend to the point of creating a problem. Two inch steal conduit available in most home improvement stores makes an excellent roller. Fence pipe may also be used.

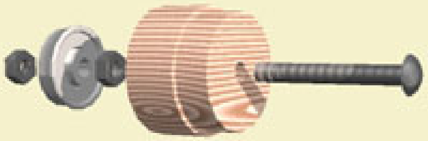
Figure 1: Details of the roller plug assembly.

Once your roller bar material is selected, you must plug both ends with a wooden end plug that contains a centered hole. The O.D. of this plug must be flush with the roller bars, otherwise the shell will not be supported evenly on the rollers. The pivot hole must be exactly centered in the plug or the bars will wobble while spinning. With heavier shells, this off centered rotation can make rolling quite difficult.

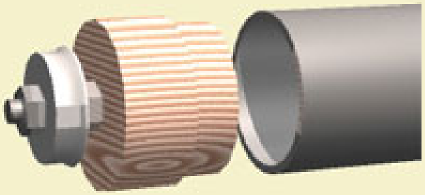
Figure 2: Inserting an assembled plug into the conduit.

The plugs illustrated in Figure 1 were cut from spruce using a wood lathe. All four plugs were cut from a 10" long piece of round stock turned down to the O. D. of the conduit. Two inch wide bands were then shaved down to the I.D. of the conduit, with a 1/2" spacing between each band. These were then cut apart by resting a notched hand saw on the tool rest and bringing it down onto the plug sections while the lathe was running. Separating the plugs in this way results in accurately faced off ends, which is important to obtain a straight center hole when drilling them on the drill press.

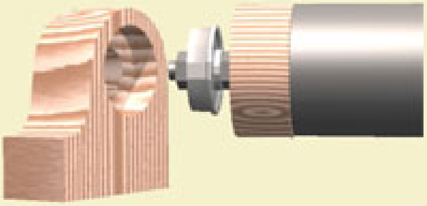
Figure 3: Pillow block with countersunk hole to accept bearings.

Since many readers probably do not have a wood lathe, an alternate method is to use a 2" hole saw to cut the plugs. This method has the advantage of leaving a centered hole in the plug. The plugs will then have to be glued or held inside the pipe using screws or pins drilled in through the conduit wall.

Once the plugs are cut, a 3/8" hole is drilled down the center of each one. A 3-1/2" long 3/8" bolt is then fed into the plug, with a lock nut tightened down from the other side to secure the bolt. A 3/8" ball bearing is then fixed to each bolt using another lock nut to hold it in place, as seen in Figure 1.

Figure 2 shows a plug assembly being inserted into the end of the conduit. The notched plug as made using the lathe method only needs to be a slip-fit, while plugs without the outer lip will need to be fastened to the conduit.

Figure 3 shows the wooden pillow block that the bearings slip into. For the bearings used here, a 1-1/8" hole was drilled half way through the block, then a 3/4" hole drilled the reset of the way. This gives a countersunk seat to hold the bearing.

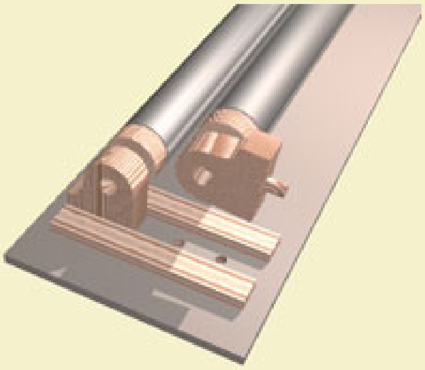
Figure 4: One fixed roller and one adjustable roller held into position with pegs.

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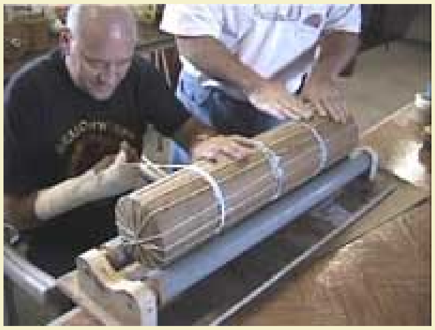
Figure 5: Using a roller to spike between the breaks of a large shell.

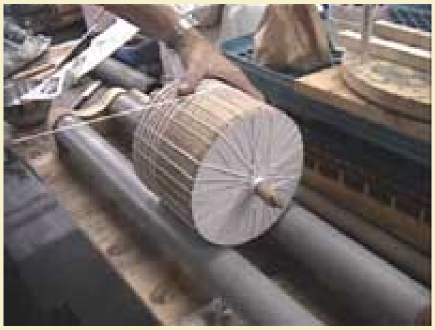
Figure 6: Using a roller to apply horizontal spiking on a bottom shot.

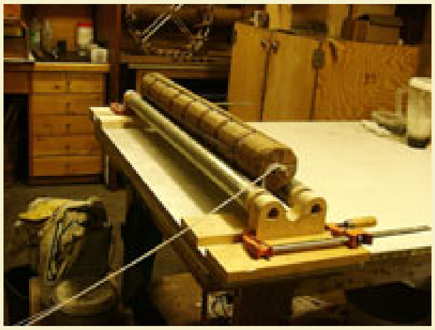
Figure 7: Roller adjusted to narrow spacing to handle a long multi-break 4" shell.

The pillow blocks are cut from 2x4 segments 4 inches long, with the grain running in the long direction (vertically). The radius of the top of the block must be less than the radius of the conduit, since some very long shells may overhang the ends of the roller. The block centers should be at least 2-3/4" above the bottom.

The two rollers with both block assemblies attached are now centered on top of the laminated shelving board, as shown in Figure 4. One roller is fixed in place using a lag screw driven in from the bottom up into the pillow blocks at both ends. The hole for the lag screw should be countersunk so that the board may rest flat on a table without hitting the screw heads.

Next the 1x2 wood strips are screwed down on both sides of the pillow blocks at each end, forming a slot for the other block to slide in, as seen in Figure 4.

The sliding roller bar will be the adjustable side, allowing different sized shells to fit between the rollers. Two or three 3/8" holes are drilled in the center of the track at both ends, making sure each hole is spaced the same distance from the edge of the fixed pillow block. A 1" long peg is now set into the bottom of the detachable pillow blocks such that 1/2" of the pin protrudes. Both ends of the adjustable roller should easily drop into the alignment holes and hold the roller in position during use.

Applications:
The primary use for this shell rolling tool is to aid in the application of spiking twine. It may be used when horizontally spiking single breaks, as seen in Figure 6, or more commonly when spiking between breaks as shown in Figure 5. In both these scenarios, the spiking twine his held firmly in one hand while the shell is rotated on the rollers with the other hand.

My own method for spiking with a roller involves using one foot to hold the twine down on the floor while both hands spin the shell and guide the string into place. The twine passes between the folds of a sheet of newspaper, which is held to the floor by standing on it with one foot. The amount of body weight shifted to the foot holding the twine down will control the tension in the string as the shell is rolled.

This roller may also be used in conjunction with a special press when assembling the breaks of a Maltese style shell. Instructions for building the press and how to use it with this roller will appear in a future article.

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Tool Tip... **Page 1**

Maltese Comet Pump

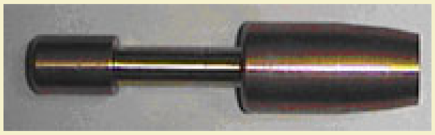


Figure 1: A Maltese comet pump.

Introduction:
In October of 2002 Benny Faruggia and Paul Schembri visited the Florida Pyrotechnic Arts Guild, bringing with them many ideas and techniques from Malta. One of the tools they shared with us is this simple comet pump, which allows damp composition to be quickly loaded and ejected without the need for trimming to maintain size consistency. With a little practice this is a very fast way to pump stars. I'm told once it's mastered you can pump 5 kilos (11 pounds) in an hour and a half or better.

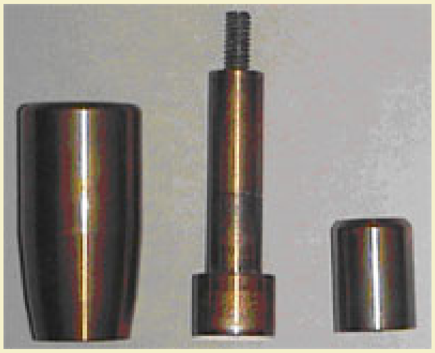
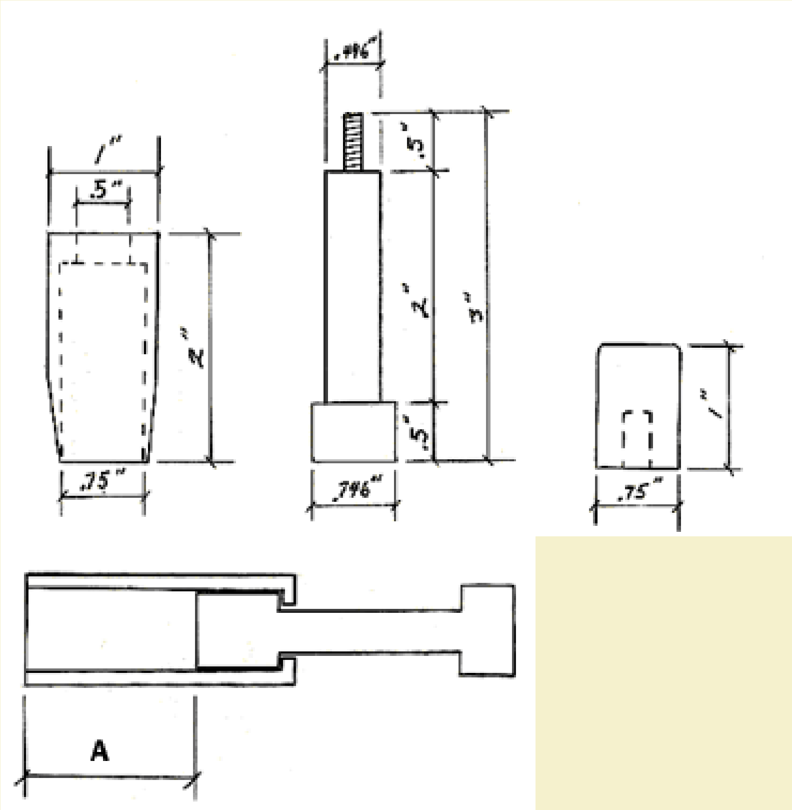


Figure 2: Components of the pump include sleeve, piston and pounding nub.

For this article I will describe a ¾" diameter pump. The description and pictures below should give enough insight for anyone with a lathe to be able to make this type of pump.



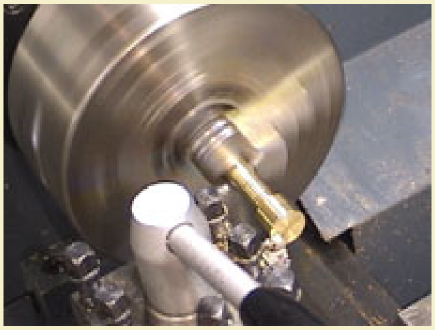


Figure 3: Turning the piston from a piece of 3/4" brass rod.

The design of this pump is totally different from what we are use to. The sleeve is made from a solid piece of 1" dia. brass bar stock 2" long. It is rough bored with a series of drill bits to a depth of 1-3/4". Then using a boring bar the finish cuts are made for a smooth inside surface. Next a ½" dia. hole is bored through the final ¼" of the bar stock.

The ram is made in 2 parts. The first part is what I refer to as the piston and

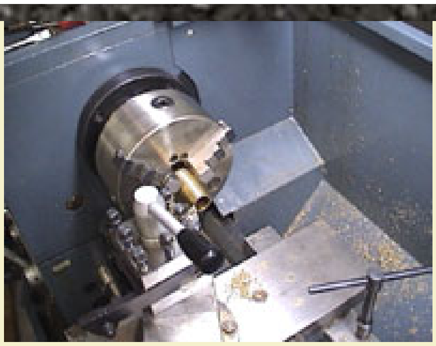


Figure 4: Turning a taper on the brass sleeve allows easier insertion into dense comp.

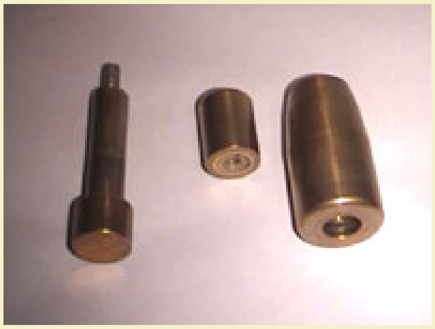


Figure 5: Completed components ready for assembly.

the second part is the pounding nub. The piston is made from a piece of ¾" dia. brass bar stock 3" long. It is turned as shown in the picture below. The threaded end does not need to be made in one piece as shown in the diagram. The bar stock for the piston can be cut ½" shorter, drilled and then taped to accept a piece of ¼" - 20 all thread.

The final piece is the pounding nub. It is made from a piece of ¾' dia. by 1" long brass bar stock. It has the edge of one end slightly rounded and the opposite end is drilled and taped for the ¼" – 20 stud on the piston.

All three parts should have any rough edges removed and be polished. To assemble the pump the threaded end of the piston is slid through the ¾" end of the sleeve and out the ½" hole in the opposite end. Then the pounding nub is screwed onto the piston. The pump is now ready to use.

When using the pump simply slide the piston all the way against the back end of the sleeve and fill with dampened star comp. The sleeve is not rammed into a pile of damp comp. as typically done, rather the comp. is pressed into the sleeve using your fingers. This eliminates the density inconsistency that occurs when loading comet pumps by ramming them into a pile of damp comp.

Once loaded, press the comp. using a mallet or a press. At first it will take a little practice to load the pump to the same density each time so the stars will all come out the same length. I played with 500 grams of wet star comp and had the hang of it in about 45 minutes.

The pump described in this article has a cavity dimension (A) of 1-1/4". In my tests the stars pumped were 7/8" tall. To make the stars shorter the sleeve can be turned down to a shorter length or a washer like spacer can be made. The spacer should be placed on ½" diameter of the piston shaft before the pump is assembled. The intent of the spacer is to allow less travel in the piston. This allows less volume in the cavity, which in turn makes a shorter star.

Special Thanks to Benny Faruggia for sharing his paten with us.

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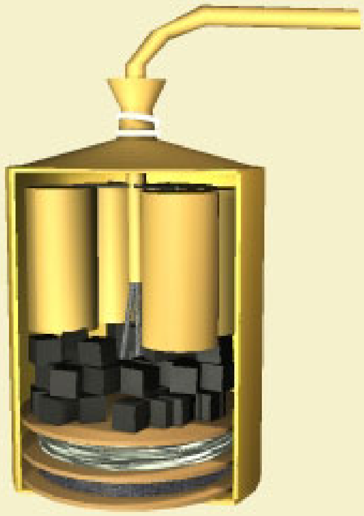
Volume 3, Issue 5

Build This...

4" Mine w/Saettines



June, 2003 Issue

Build This:
4" Mine w/Saettines

Design Notes:
Ball Milling Theory

Tool Tip:
Build Your Own Ball Mill

Tool Tip:
Maltese Comet Pump

Class C Corner
Dumb Blonde, Extreme Machine

Summary:
Mines are among the quickest items to prepare and are ideal for disposing of old stars or leftover shell components that are taking up space in your shop. These pyrotechnic "shotguns" are simply bags of components with a small quantity of lift charge at the bottom, usually with a disk or piston between the lift and the components to help push them out of the mortar.

This article shows the construction of a simple 4" star mine containing saettine inserts, which are Italian salutes that use a clever combination of sawdust and black match to achieve delay after ignition.

Materials:

- (7) 2-1/2" x 7" long manila file folder paper
- (7) 4-1/2" x 7-1/2" 70lb kraft, grain short
- (7) 5" long single strand black match
- (7) 2" square scraps of 30lb kraft
- (3) 3-1/2" diameter 1/8" chipboard disks
- (1) sheet newspaper
- (1) 11-1/2" x 24" 40lb kraft
- 40g 2FA black powder
- 1-1/3 cup of stars
- quickmatch leader

Tools:

- 1" dia dowel rod
- rubber mallet
- glue brush
- 3-1/2" dia case former
- spiking horse

Unmeasured Materials:
white glue, cotton twine, paste, sawdust, 70-30 flash

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Volume 3, Issue 5

4" Mine w/Saettines

Page 2

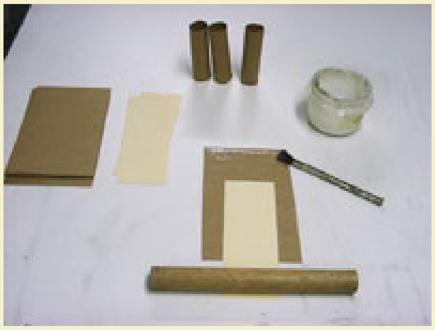


Figure 1: Paper cut and ready to roll saetine cases.

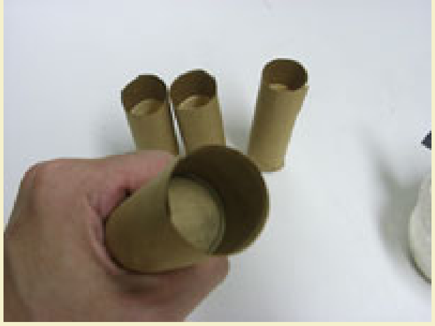


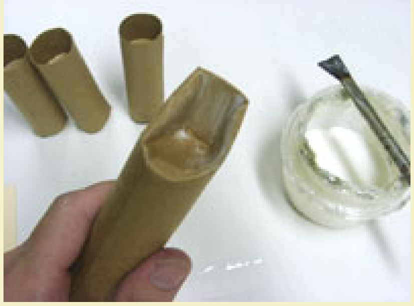
Figure 2: Dowel even with tag board prior to folding the overhang.

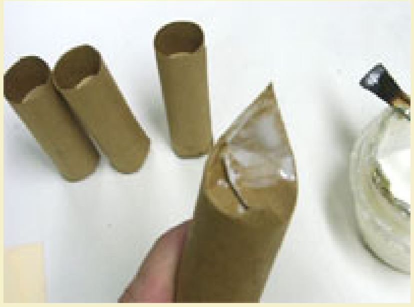
Making the Saettines:

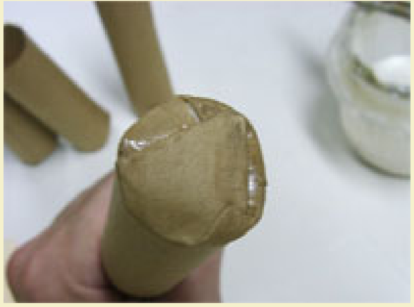
Saettines, also spelled siatenes or citeens or alternatively called lambetti, are a type of small report used in shells and mines. What sets them apart from other types of reports is the method by which they achieve their delayed timing. The simple paper casings are only partially filled with flash powder, into which a single strand of good quality black match is inserted. The remainder of the space is rammed with sawdust or bran such that it surrounds the black match and prevents the gasses from shooting along the sides as in piped match. This creates a reliable delay that, while not as accurate as time fuse, does the job quite well when a random barrage of salutes is desired following a color break shell or colored star mine.

Saettines are quick and easy to make, since they require no special tubes, disks or time fuse. The ones described here will measure 1" diameter by 2-1/2" long. You will only need seven to complete the 4" mine for this project, but you might as well make a good number of them because you will find yourself wanting to use them a lot and of course in fireworks, more is always better!

The case for saettines are made by rolling two pieces of paper together at once. An inner liner is made from thin chip board or manila file folder paper measuring 2-1/2" wide x 7" long. This will give you two turns around a 1" diameter case former. One 14" legal size file folder will give you enough strips to make a dozen saettines. The outer strip of paper shown in Figure 1 is a piece of 70lb kraft measuring 4-1/2" wide by 7-1/2" long, with the grain running in the short direction. The liner is placed over the kraft so that it overhangs a few inches on the end you are rolling from. The kraft is glued at the edge and the two sheets are rolled up together.


Step 1: Making the triangle fold


Step 2: Second fold.


Step 3: Third fold.

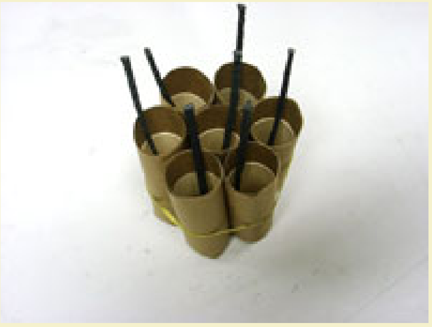


Figure 3: Bundled and fused cases ready to load.

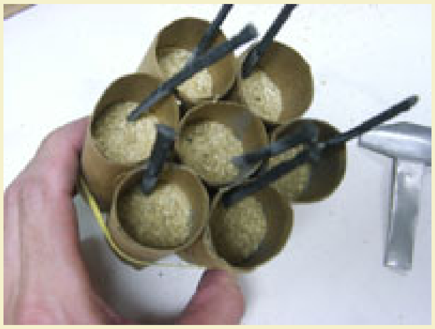
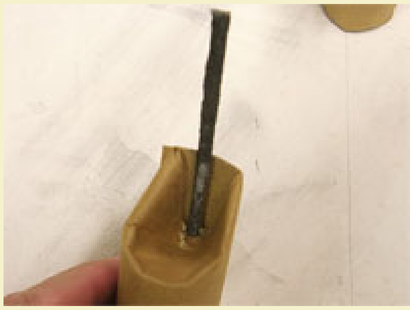


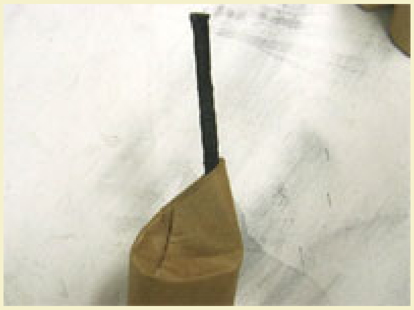
Figure 4: Packing in the sawdust for delay.

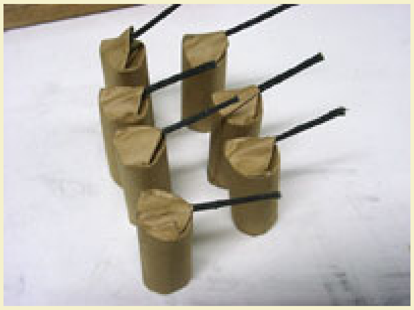
Both ends of saettines are closed by a simple fold known as the "triangle fold." The case former is slipped down so that it is level with the inner liner. Steps 1-3 above shows how the overhanging kraft paper is folded to form the bottom of the saettine. I like to apply glue after each fold to help the pleated paper stay down. After the last fold is made, place the bottom of the case on a table and rap the case former with a rubber mallet to make the end good and flat.

As you might guess, this folded end plug is not reliably gas tight. While some claim that proper construction results in a good seal, having your shells detonate from a gas leak in one single saettine is not the best way to verify this claim. There are two methods commonly used to guard against gas leaks setting off your saettines. One is to ram an initial scoop of sawdust into the bottom of the case prior to loading the flash. The other is to paste a small square of lightweight kraft over the bottom of the case after it is loaded. I personally prefer the latter method.

Begin loading your cases by bundling them together and inserting a 5" stick of black match in each one. The quality of your black match is important, since only one strand can be used. Using multiple strands will cause a fire gap between them that will ruin the delayed effect.


Step 1: First fold


Step 2: Second fold.


Step 3: Third fold.

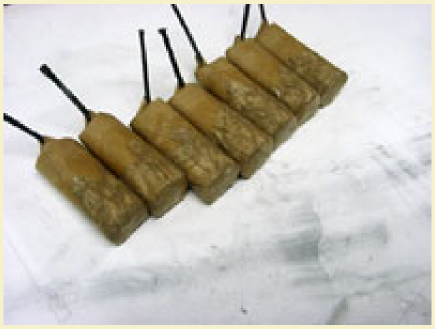


Figure 5: Pasted paper over bottom protects against gas leaks.

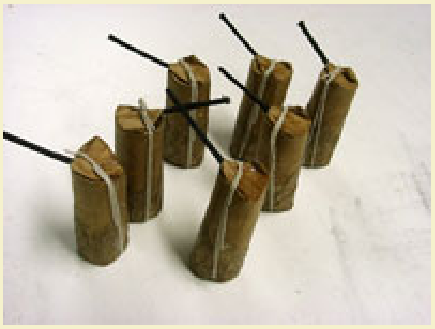


Figure 6: A clove hitch made with pasted cotton twine secures the ends.

Next load the flash powder into each case, leaving anywhere from 20% to 50% unfilled depending on how much delay you want. The unfilled space is then loaded with sawdust and tamped down to form a tight seal around the black match, which should run down the side of the case as seen in Figure 4. Note that while this consolidates the flash, it does not effect the performance of the salute. This reality is contrary to the belief sometimes held that salutes should contain only loose flash with some air space around it.

The next series of photos above shows how the triangle fold is made around the protruding black match, only this time no glue is used. Figure 5 shows the pasted kraft paper gas seal around the bottom of the loaded saettines. Omit this step at your own risk!

The saettines are finished by looping a clove hitch around the case to hold the ends down. Cotton twine wetted with wheat paste makes a good cinch when tying them off. Allow them to fully dry before loading them into any mines or shells.

WARNING: saettines are only to be used as components of other shells or mines and should never be used as hand held ground bombs. Salutes of any type using black match as the ignition method should never be lit by hand, especially when holding them!

More...

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4" Mine w/Saettines

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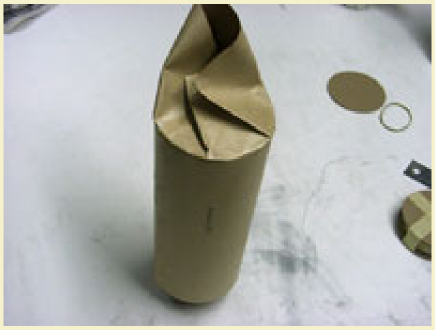
Figure 7: Pleating the bottom of the mine bag.

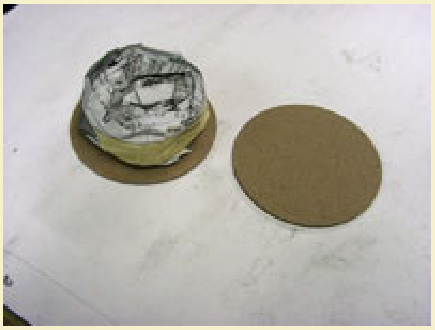
Figure 8: Piston made with wadding between two solid disks.

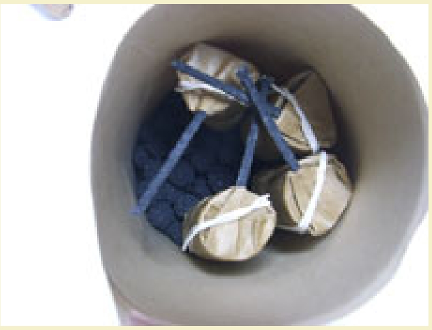
Figure 9: Loading the saetines.

Assembling the Mine:
Mines are nothing more than bags of components that are blasted from a mortar with a small lift charge. Since the container and components do not have to withstand the violent forces of being fired from a mortar while remaining intact, the construction of a mine can be quite flimsy. I've seen 12" mines made with nothing more than a grocery bag with a pound or two of 2FA in the bottom, a pizza disk over that and a whole-lotta pyro piled on top!

This mine is a bit longer than the average 4" star mine due to the inserts being used in addition to the stars. Cut a sheet of 40lb kraft that is 11-1/2" wide and 24" long, then roll it up over a 3-1/2" diameter case former just as if you were making a shell. A chipboard disk is dropped into the end while the case is still on the former, and the overhanging paper is pleated down as seen in Figure 7. You can use tape, gummed paper or glue to hold down the pleated paper.

Next slide the case off the former and load 40g of 2FA lift charge into the bottom. This is all you will need to hurl your goodies high into the air.

The next component has a lot of variations with various theories as to it's effectiveness. A piston device is placed above the lift charge, on which the rest of the mine contents will rest. The purpose of this piston is to give the list gasses a platform to push against and more effectively use the lift charge to launch the components higher. Some builders use nothing but a single chipboard disk. Some believe that this single disk is subject to rotation during lift, allowing the lift gasses to slip by and lose some height reached by the mine contents. Various methods can be used to make a thicker disk that will be less likely to rotate in the confines of the mortar. Figure 8 shows the method that I prefer, which is to sandwich a wadding of newspaper between two disks and hold them together with a few pieces of tape.

Mines are typically ignited by sending the passfire to the stars first in order to insure that they are lit before the lift charge ignites. Some builders run raw black match all the way down into the lift charge and up through the star chamber. Many people punch holes in their disks or notch the edges, believing that this is required in order for the fire reach the lift charge once the stars ignite. These holes then further require the lift charge to be contained in some sort of bag to prevent it from migrating out the holes and into the star chamber during shipping and handling.

However, none of this extra work is necessary and you can simply use solid disks without any problems. It is always far more difficult keeping hot gasses out than allowing them to get in, and even the slightest hair thin gap around your disks would allow for easy ignition. The reality is that the entire inside of the mortar becomes a high pressure inferno and the thin outer wrap splits away in the first fraction of a second, easily allowing the lift charge in the bottom to ignite.

After dropping the piston into place over the lift charge, add about 1-1/3 cups of round or cut stars on top. This should give you a 2" high column of stars. The saettines are loaded in right on top of the stars. Some builders suggest that placing the saettines fuse end down will reduce the likelihood of a gas leak detonating one of them accidentally. However, if you have prepared the bottom end of your saettines as previously mentioned in order to make them gas tight, it should not matter how you orient them in the mine.

Run your leader down between the saettines so that the bare match rests on top of the stars. The remaining paper is simply collected around the leader and tied of with a clove hitch.

The effect should be a burst of colored stars with a delay before seven loud flashes of white light appear over top of the star column.

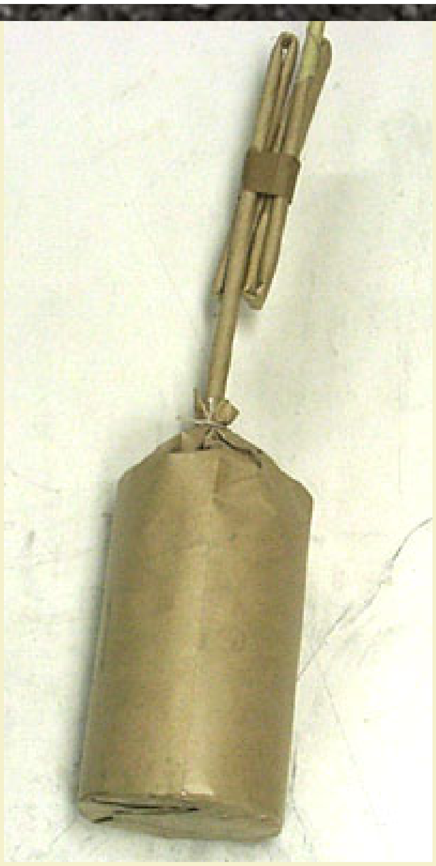
Figure 10: Finished mine ready to fire.

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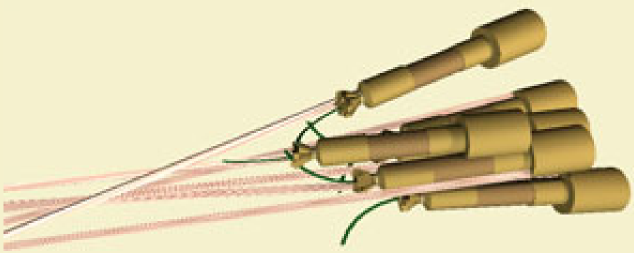
Volume 5, Issue 1

Build This...

1/2" Black Powder Rocket



February, 2005 Issue

Build This:
1/2" Black Powder Rocket

Troubleshooting:
Shell Lift Failures

Quick Tip:
Finding Paper Grain Direction

Tool Tip:
Mass Rocket Launcher

Autopsy:
19 Shot Cake

Summary:

This 1/2" I.D. black powder rocket, known as a 4 oz. rocket in the traditional nomenclature, is a great starting point for anyone building their first rocket. This little rocket can carry a 20 to 25g payload straight up without a struggle, with nice headings that put most similar sized commercial rockets on the market to shame. The entire process of creating all components is covered, including making the tooling, rolling the engine tubes and cutting your own rocket sticks.

Formula: 4 oz. Black Powder Rocket

Materials:

- (1) 4" x 14-3/4" long manila file folder paper strip
- (1) 4" x 5" 30 lb kraft
- (1) 3" x 12" 60 lb recycled kraft
- (1) 3/16" square x 24" long wood stick
- 1 TSP powdered clay
- 3" visco or black match fuse

Tools:

- 4 oz. rocket tooling
- brass hammer
- solid ramming base
- hot glue gun
- drill press or hand drill
- 1/8" drill bit

Unmeasured Materials:

hot glue, waxed linen twine or wire, powdered clay, 2Fg, stars

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1/2" Black Powder Rocket...

Page 2

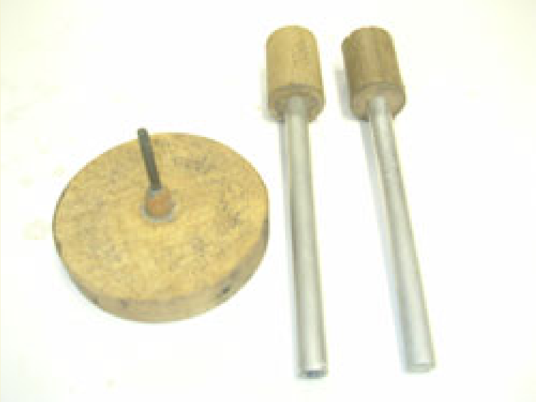

Figure 1: Home-made rocket tooling.

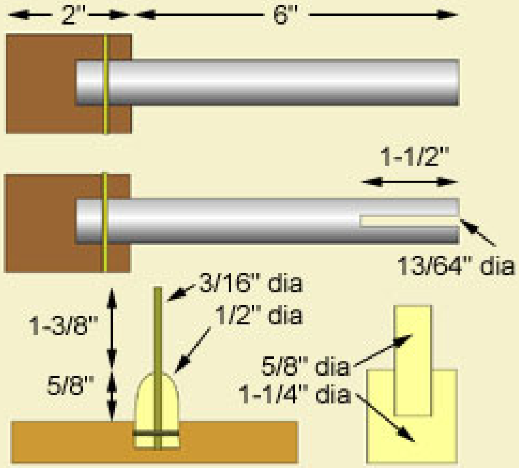

Figure 2: Dimensions for rocket tooling.

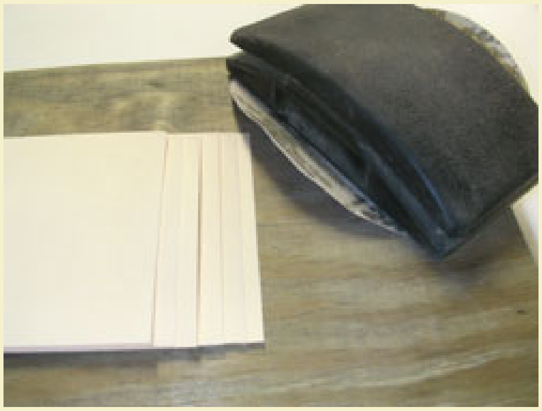

Figure 3: Feathering the edge of manila strips using sand paper.

Introduction

At one time in pyro history, rockets were the primary means for creating aerial displays. Aerial shells naturally replaced them due to their ability to lift considerably more effects into the air using less materials and effort, but the rocket is actually among the oldest effects next to fire crackers and roman candles. For most pyros like myself who retain vivid childhood memories of their backyard 4th of July experiences, rockets were always the most exciting type of firework to have in your possession. Not only did they simply look cool by design, having rockets in your 4th of July arsenal gave a sense of power. While your neighbors would be standing around ground fountains or other land-based spinners, you would be getting everyone's attention with swooshing rockets traveling 100s of feet into the air!

The rocket described here is one of my favorite sizes, due to the speed of construction, low volume of powder consumed yet still enough lift to take up an attractive header. The small size allows firing them in your backyard without worrying about heavy sticks doing damage when they come back down, a problem that plagues larger rocket use in all but spacious, uninhabited clearings. This is also one of the most popular sized class C rockets for the same reasons, although most commercial versions I've seen tend to have sparse, disappointing headers.

The traditional nomenclature for this 1/2" I.D. rocket would be a 4 oz rocket. This strange, seemingly meaningless weight designation has nothing to do with the actual weight of the rocket or how much it can lift. From what I have been told, the weight represents the weight of a lead ball that would fit into the engine tube. I never weighed a 1/2" diameter lead ball to verify if it does in fact weigh 4 oz, mainly because it doesn't matter. Pyro literature is already cursed with this bizarre rocket size designation and, probably out of tradition, people continue to use it to this day. Thus you, the aspiring rocket builder, must memorize a table that maps rocket I.D.s to irrelevant weights in order to converse with your fellow rocket builders.

Common BP Rocket Engine Sizes

Size	I.D.	Length
2oz	3/8"	2-3/4"
4 oz	1/2"	5"
8 oz	5/8"	6-1/4"
1 lb	3/4"	7-1/2"
2 lb	7/8"	10"
3 lb	1"	10"
4 lb	1-1/4"	12"
6 lb	1-1/2"	16"

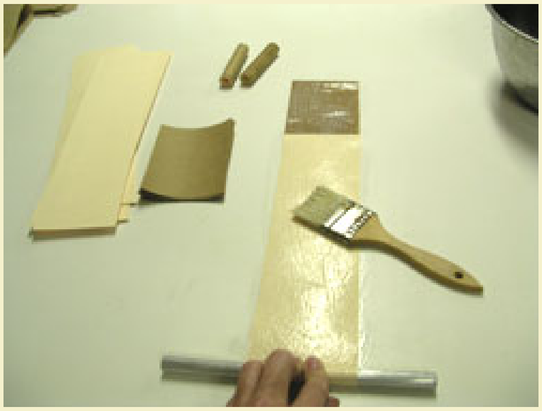

Figure 4: Rolling the rocket engine tubes.

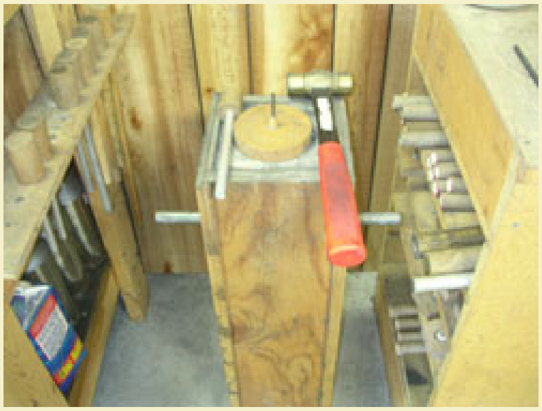

Figure 5: A cement filled ramming block and brass hammer for loading the engines.

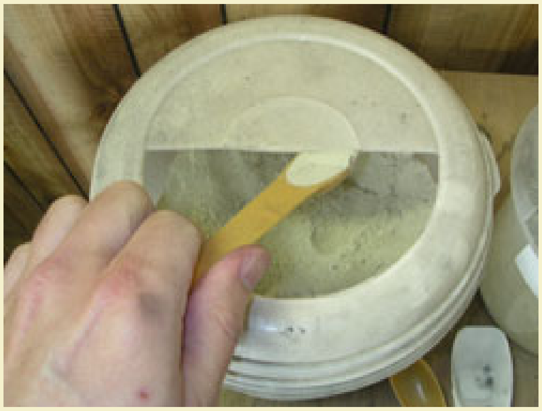

Figure 6: Container lid modified to make leveling the measuring scoops easy.

Building the Tooling

Special rocket tooling is usually required due to the inner cavity required at the center of the powder core when building black powder rockets. This cavity increases the surface area of burning powder, thus giving more thrust than if the powder core were merely burning from end to end. This trick allows you to use slower burning fuel that has more charcoal added in order to produce better tail effects.

Usually the powder core is conical in shape, but this small rocket employs a simple cylindrical core. This feature makes it possible for you to build your own tooling, since a simple brass rod can be inserted into a wooden nipple that has been sanded to produce the rounded off shape shown in Figure 2. Two rammers are required, which are known as "drifts" in the rocket world. One rammer has a hole in the center so that it can fit over the spindle when ramming the clay plug and the powder increments up to the end of the spindle. The final increments and clay plug are then rammed with the second rammer that does not have the hole.

Larger rockets with a tapered spindle would require several drifts, each having a progressively smaller hole in the end. The spindles are used in order from largest hole to smallest in order to keep the clearance minimized as the powder core is built up around the spindle. Each drift has to be marked in order to indicate when the next drift should be switched to. Switching to the next drift too early can result in the spindle getting wedged into the rammer hole and damaging the tooling.

You don't have to worry about switching out multiple drifts when building this simple rocket, just load until you can't see the spindle anymore, then switch to the solid drift. In fact, you could omit the spindle altogether and just ram a solid core if you wanted, then bore it out on a drill press using a 3/16" bit to a depth of two inches beyond the top of the casing. This of course requires that you put up with the uneasy feeling of drilling a rather long hole into live composition. Drilling into BP is actually pretty safe at low speeds since black powder has very low sensitivity to friction, and I have made many rockets this way.

The most difficult part of making the tooling shown in Figure 2 is drilling the 13/64" center hole into the end of the first drift. A drill press is necessary for this, and a good clamping device that can hold the rammer rod exactly perpendicular to the drill table. A right angle gauge must be checked all around the rod to make sure it is perpendicular to the table in all directions.

While wooden dowel rods can be used to make the drifts, I prefer to use aluminum. When wood is used, the center hole in the first drift tends to become larger over time due to glancing blows off the spindle during loading.

The other object in the tooling diagram is a special case former for making the header, which is just a 2-1/8" long 1-1/4" dia. dowel rod with a smaller 5/8" dowel rod recessed into it at the center. The smaller rod should extend about 1-1/2" out from the larger one.

The other tools you will need include a solid ramming block, a brass hammer and a small paper funnel. The funnel can be easily made from a scrap of paper, with the hole sized to just under 1/2" diameter. A regular hammer can be used if your rammer has a wooden head, otherwise brass or other non sparking metal is required. I prefer the brass mallet style hammers for their heavier weight and the ends which are smoother, flatter and wider than a normal hammer. This helps prolong the life of your ramming drifts compared to using a typical carpenter hammer.

Figure 5 shows a rocket ramming station. The central ramming block is a long plywood box filled with concrete to eliminate vibrations while ramming. Be sure to embed a metal T handle through the box before pouring the concrete if you plan to make one of these, otherwise it is very difficult to move around! A solid block of wood can also be used for this purpose. The height of the block should be such that it sits at waist level when seated in front of it.

More...

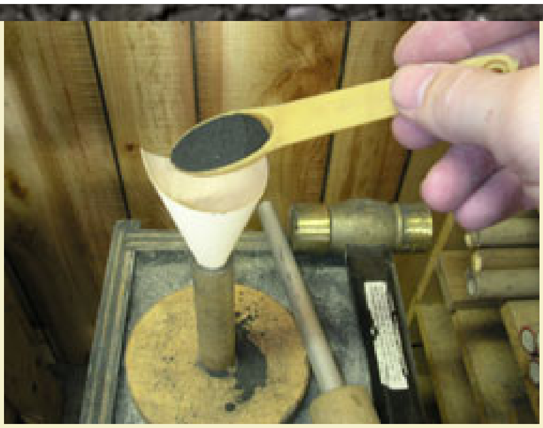
Figure 7: Adding a 1 TSP (5 ml) increment of BP fuel.

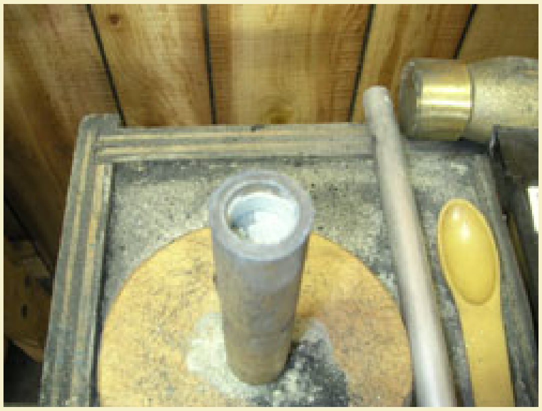
Figure 8: The clay end plug rammed in place.

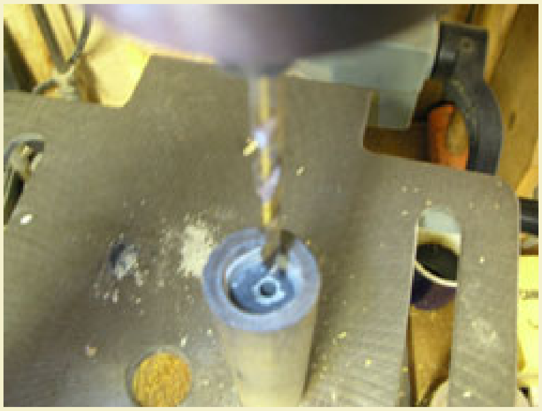
Figure 9: 1/8" passfire hole drilled through end plug.

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Volume 5, Issue 1

1/2" Black Powder Rocket...

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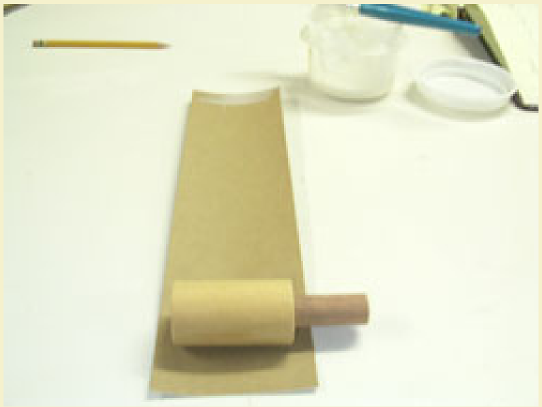

Figure 10: Rolling the header on a special former.

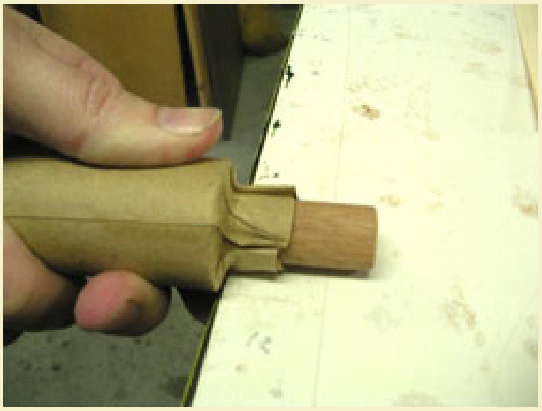

Figure 11: Reducing the diameter on the end that connects to the rocket.

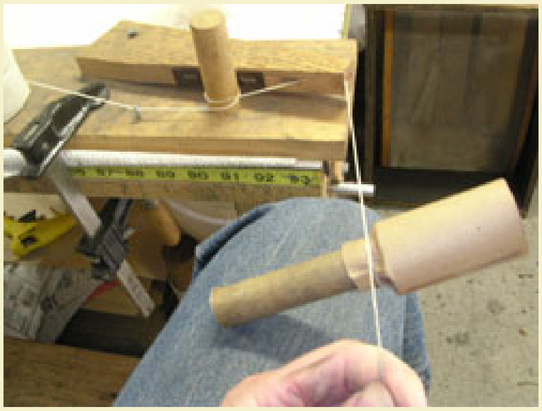

Figure 12: Using a spiking horse to apply a tight half hitch over the glued header collar.

Making the Fuel:

The formula for the rocket engine is designed to work with home-made spruce charcoal, which makes a very fast burning black powder. If you are using commercial air-float or some other source of charcoal, you may need to increase the potassium nitrate percentage in order to account for the slower burn rate.

Ingredient	Parts	Ball Mill (800g)
Potassium Nitrate (KNO3)	14	589 grams
Charcoal Airfloat (C)	3	126 grams
Charcoal 30-100m (C)	3	not milled
Sulfur (S)	2	84 grams

NOTE: 126 g of coarse charcoal is screened in after the other components are ball milled.

All components except the coarse charcoal are ball milled together just as if making meal powder. The coarse charcoal is then screened in after milling. The charcoal I use for the coarse type is anything that passes a 30 mesh screen after grinding my homemade charcoal, so that has a particle range from 30 mesh all the way up to fine dust.

While spruce charcoal makes a very strong powder, it lacks in producing the optimal spark trail compared with other charcoals like yellow pine. A better tail would result from using yellow pine as the coarse component.

Rolling the Casing:

While commercial tubes can usually be found for this size rocket without much trouble, it is also easy to roll your own high quality tubes from manila file folder paper. Four rocket tubes can be made from a single legal size file folder, which will provide 14-3/4" long strips of paper that allow a casing to be made from just a single strip. The folders are cut up into 3-1/2" or 4" wide strips, depending on the length of the engine you want to make. Smaller strips of 30 lb kraft of the same width and 5" in length are also prepared for making the casings.

Because manila folder paper is fairly thick compared with kraft paper, I prefer to taper the edge that will be located inside the engine. This is done so that the inside seam will lay flat, thus removing the tiny channel of less compressed powder that can sometimes cause engine failure when rolling cases with thick paper. The manila paper is thin enough that this is probably not an issue, but it is better to be safe than sorry. Figure 3 shows how this is easily accomplished on

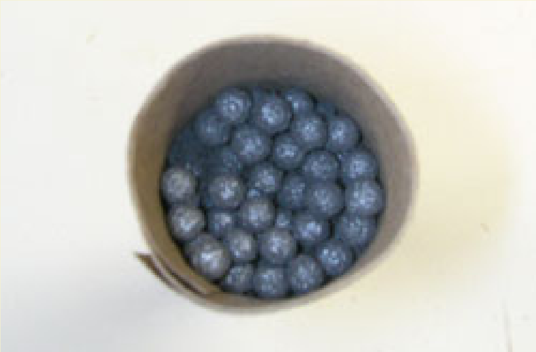

Figure 13: Loading the header with 20g of 1/4" stars and 2Fg.

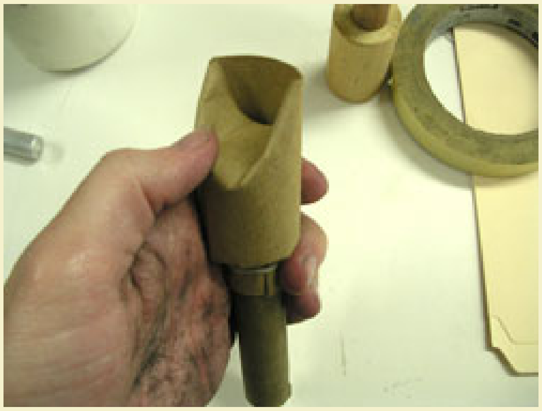

Figure 14: First fold of closing with a triangle fold.

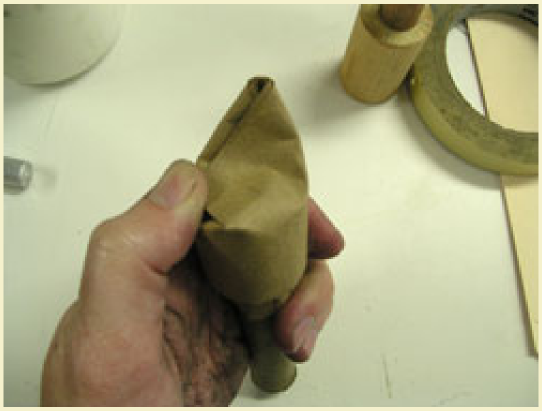

Figure 15: Second fold of a triangle fold..

several sheets at once by fanning them out and using a sanding block pulled across them in the long direction of the paper. Be sure to start rolling your tubes from the sanded end when doing this.

Because only a single strip is required, these tubes are quite fast to roll. A mixture of 50/50 white glue and water is painted onto one side of the strip as seen in Figure 4, including the short strip of kraft that is used to form the last two turns. The tubes are then rolled around a 1/2" former and set aside to dry. The manila/glue combination produces a rock hard case that does not shrink or deform upon drying, unlike cases rolled from kraft and paste.

If you are buying typical hobby supplier kraft tubes, you will want to get ones that are at least 3/4" O.D. Because the manila tubes are stronger than kraft, rolling your own allows you to get away with using a 5/8" O.D. tube and thus shed a little weight. The manila tubes are also less likely to split open when loading the rocket, unlike some of the lower quality kraft tubes on the market.

Loading the Engine:
The first step to loading the engine is to ram the clay plug at the exhaust end. This is done using 1 TSP of powdered clay, as seen in Figure 6. Cutting a "D" shaped hole in the top of your container lids gives you an easy way to level off your scoops when pulling them from the container, since you don't want heaping scoops that would result in inconsistent increment sizes.

The powdered clay used here can be just plain bentonite, or you can optionally add some grog to give the plug more bite into the casing. Grog is a type of fine grained gravel with sharp edges that will bite into the paper. However, the plug created by the tooling specified in Figure 2 provides almost 3/4" of contact with the case wall, and I've never had a problem with plugs blowing out.

After ramming the plug with the hollowed out drift, you will need to clean the clay off the end so that it doesn't get deposited on the fuel increments, since you will use the same drift to load the fuel. Each fuel increment is also 1 TSP (5ml) in size, which will result in about 5 or 6 increments to complete the rocket. Each increment should be consolidated with 4 or 5 blows from your mallet. These are not overly hard blows like when driving a nail, but they should be good, solid hits. You will get a feel for when to stop ramming when the rammer stops compressing the fuel and the hits start feeling rock solid.

When the fuel rises above the spindle and it is no longer visible, switch to the solid drift and load the casing to about 1/2" from the top. Fill the remaining space with clay and then ram the plug in place as seen in Figure 8.

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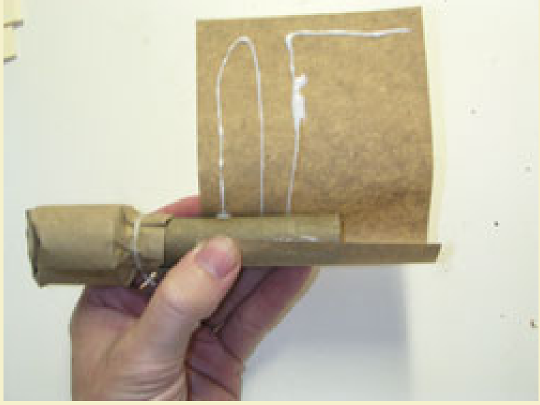

Figure 16: Applying the nosing paper to the engine prior to fusing.

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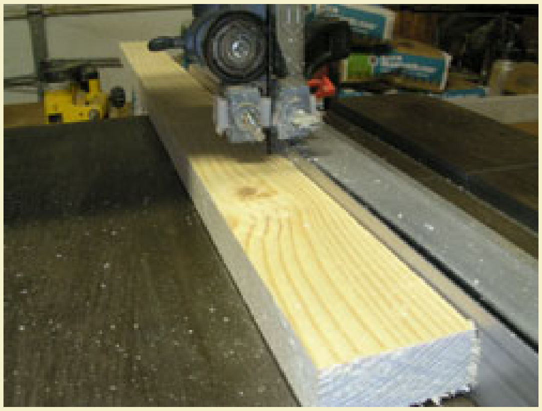

Figure 17: Making a slice off the edge of a knot-free 3/4" thick board.

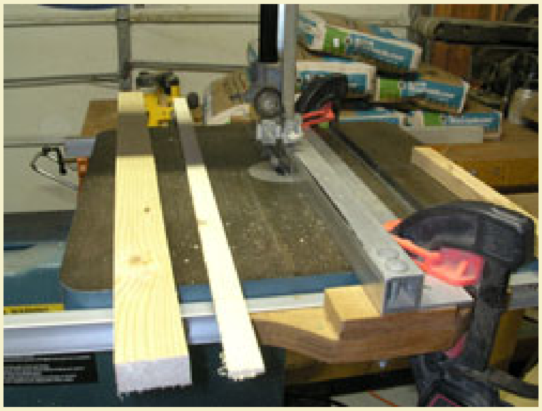

Figure 18: The slice is laid flat and is ripped into three sticks.

Making the Header:
Next you will need to roll the header casing using a strip of 60 lb recycled kraft that is 12" long and 3" wide. Virgin kraft could be used, but it will be harder to crimp the end onto the rocket casing if a stronger paper is used.

The casing is rolled on a special former as seen in Figure 10. The smaller dowel rod sticking out of the former should match the O.D. of your rocket case. Once the case is rolled and glued at the end, the overhanging paper is crimped around the smaller former as seen in Figure 11. Rolling the former along the edge of a table helps flatten down the paper.

The header is now attached to the engine by first applying glue to the end of the engine and then inserting the engine inside of the header nozzle end first. The engine is pulled through the header until it sits over the glued area. The header is now locked in place using a half hitch of waxed linen twine. Using a spiking horse when tying the header on allows you to apply a lot of tension for making a really tight knot, as seen in Figure 12.

Next the header is ready to be loaded. This rocket can lift between 20 and 25 grams of header contents, which is what a full load of color stars weighs. Start by adding 1 TSP of 2Fg black powder into the bottom of the header so that it fills the end of the engine and falls into the passfire hole. The remaining space can now be filled with either flash or stars. Cut stars will work the best, since the case does not provide much confinement and the stars need to take fire quickly. The 1/4" round stars shown in Figure 13 will still make a nice break, but a few of them are often blown blind by not taking fire before the header breaks.

The header is closed with a triangle fold, as seen in Figure 14 and 15. The last few folds can be held down by either hot glue or white glue to keep it from unfolding.

Cutting Rocket Sticks:
This rocket requires a stabilizing stick that is 3/16" square and 24" long. While you could use a 3/16" round dowel rod for this purpose, a square stick makes better contact with the rocket motor when attaching it. Square sticks are also much cheaper if you make your own, which requires a band saw.

Figure 17 through 20 shows the procedure for cutting rocket sticks from standard 3/4" thick pine scraps. Any size band saw an be used for this purpose, but the wider the blade is the less problems you will

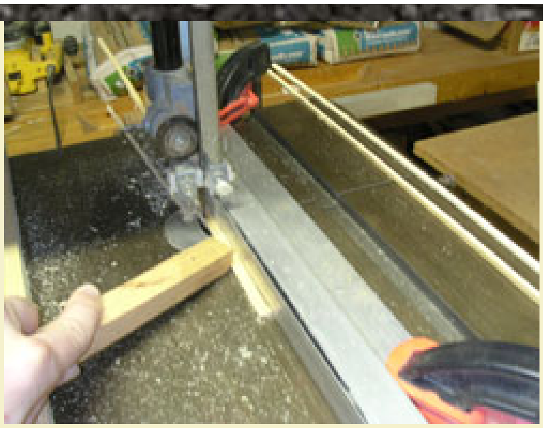

Figure 19: Using a push-stick to safely feed the tiny strip into the blade.

have trying to keep the cuts straight.

A guide fence is setup 3/16" away from the blade, with the blade tensioners set to minimize blade flexing as much as possible. The wood used for the sticks must be free of knots or other defects that would cause the s ticks to break easily when cut to size. Pine and cedar work well because of their light weight, while hardwoods like oak and poplar add unnecessary weight to your rocket.

Start by cutting the wood scrap to the desired length of the stick, 24" in this case. Then begin cutting slices off the edge as seen in Figure 17 and 18. Each one of these slices is then fed through again to produce three completed sticks. Note that a push stick must be used when cutting such small strips, as seen in Figure 19.

Many sticks can be produced from even a small scrap of wood using this method. Figure 20 shows several sticks made from less than an inch of 3/4" thick material.

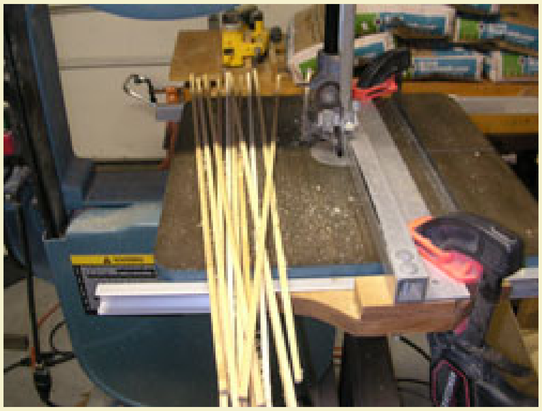

Figure 20: Dozens of rocket sticks cut from a small stick of wood.

Finishing the Rocket:

Before gluing the stick to your rocket, you need to roll some nosing paper onto the fuse end, which will be used to crimp around the fuse so that it doesn't fall out. Figure 16 shows the glue pattern for applying the nosing paper, which is a 5" long strip that should form two turns around the engine.

The last step is to glue the stabilizer stick to the engine, as seen in Figure 21. This can be done with hot glue for quick assembly, or white glue with tape can be used. Some builders attach the stick before the nosing paper, then wrap the nosing paper around the stick as an additional means of fastening it to the engine.

A 3" long stick of visco or black match is inserted at least half way up into the nozzle cavity, then tied off with the nosing paper to finish the rocket.

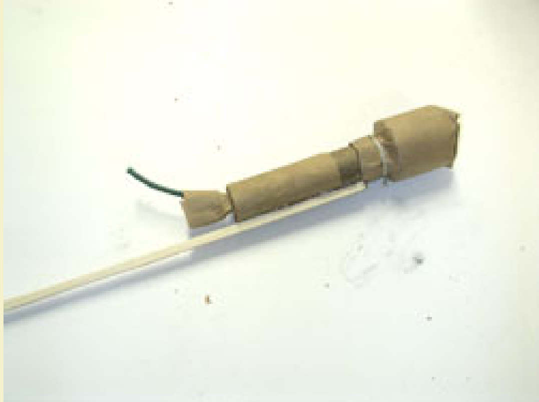

Figure 21: The completed rocket with stick glued in place.

If you rockets will be fired in close proximity to other rockets, such as when launching many at once using something like the Mass Rocket Launcher described in this month's Tool Tip article, then it is a good idea to add an extra spark barrier to the header so that exhaust sparks coming down on it from above do not work their way into any gaps and ignite the header. A piece of pasted 30 lb paper or even foil tape placed over the top of the header will do the trick. Alternately you could fabricate nose cones out of paper to be glued on top, which would also help reduce drag during ascent.

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Tool Tip...

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Adding a Gauge to Your Bottle Jack

by **Patrick (Doc) Ferguson**

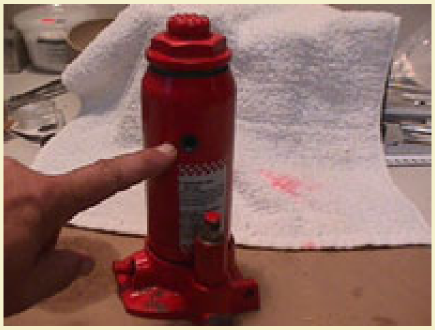

Figure 1: Remove the oil plug and drain all fluid.

Introduction:

Inexpensive bottle jacks have long been popular among rocket and fireworks builders for pressing operations that require several tons of force. However, there is no way to tell how much pressure is applied with these jacks, which is useful information when trying to get consistent results from items such as rockets, comets, black powder pucks etc.

This article shows how to add a pressure gauge to a typical bottle jack. The jack used here is your run of the mill cheapo from Harbor Freight or other discount supply houses. This one is a 4 ton unit, but the six ton and higher are constructed nearly the same.

Dismantling the Jack:

Start with removal of hardware for the handle to get it out of the way. Set the parts in a safe place so you don't lose them.

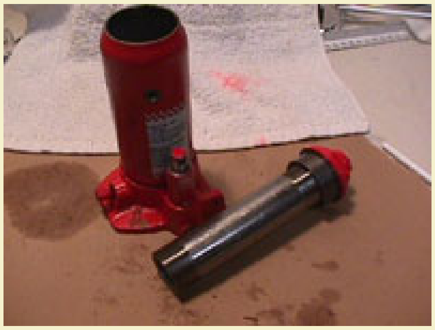

Figure 2: Removal of the piston.

Next remove the oil fill plug and drain the fluid into a container. You will need to pour this fluid back into the hole when you are finished. Figure 1 shows the typical location for the oil plug plug.

The large nut at the top of the jack must now be removed. Secure the jack base in a large vice and use a pipe wrench to fit around this nut. The use of a cheater bar is recommended, which is a short length of pipe that can be used to extend the wrench handle for more leverage. Once the nut is loose, you can unscrew it by hand and remove the piston, as seen in Figure 2.

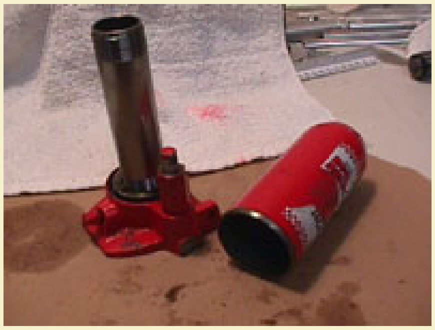

Figure 3: Removing the outer case.

The outer casing is now removed from the reservoir unit. Now comes the real bear! The removal of the inner sleeve that is screwed into the reservoir by two men and a boy from China. This will take a good vise to hold the unit. Using a pipe wrench again with the cheater bar, turn it counter clockwise to loosen.

Tapping the Reservoir:

Figure 4 shows where you will need to drill holes into the reservoir base. You will need to drill small pilot holes first using a 1/16" bit, then drill again using a 1/8" bit. The hole in the side will need to be tapped for a 1/8" NPT fitting.

I have opted to put the gauge on the side opposite where the pump handle is so that it can be easily read while pumping the jack.

More...

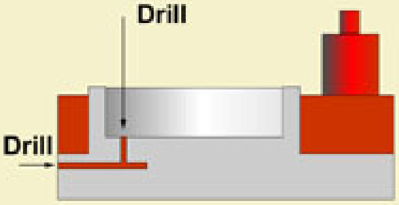

Figure 4: Cutaway view showing where to drill your access holes.

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Adding a Gauge to Your Bottle Jack...

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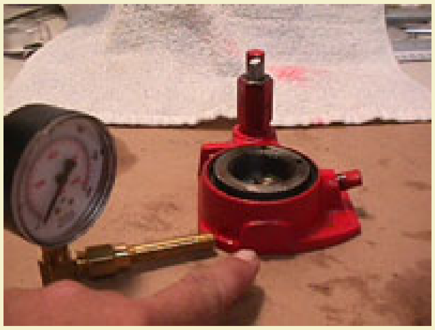

Figure 5: Using gauge assembly to mark center of side hole.

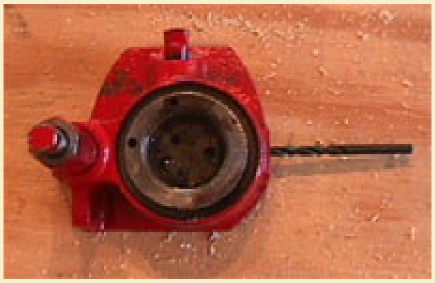

Figure 6: Checking the depth of the side hole.

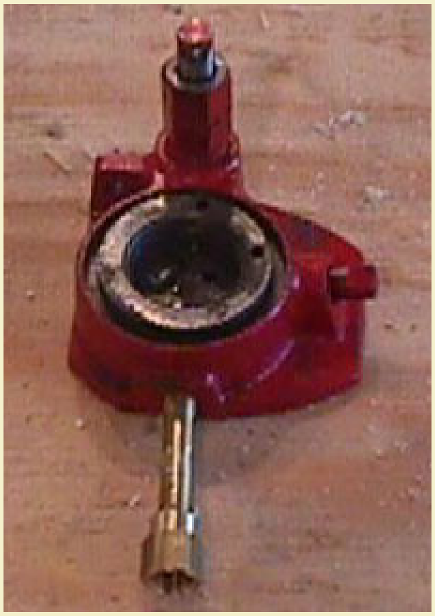

Figure 7: Test fitting the 1/4" fitting.

Before drilling any holes, first set your gauge just to see where center should be located, as seen in Figure 5. Use a center punch to make a dimple where the hole will be drilled. This will keep your drill bit from "walking" off the spot where you want the hole.

Drill the side hole first. I would suggest using a drill press machinist vice if you have one or you will have to rely on a friend to hold this good and tight while you drill. The metal is very soft so it has a tendency to grab. Take your time.

Now you need to find the center of the hole you drilled into the side. Make a small pilot hole first again, stopping once you intersect the hole you put in the side.

Once you have drilled through the top and struck the cross drilled hole you can insert a bit to see that your channel is deep enough, as seen in Figure 6.

Now that you have a good pilot hole you can drill and tap for 1/8" NPT thread. Try your fitting out to see that you have enough threads, as in Figure 7. Note that hydraulic fittings are used between the jack and the gauge, due to the low pressure ratings of standard plumbing fittings. Most small bottle jacks will generate between 5000 and 7000 psi, which far exceeds the pressure ratings of plumbing fittings.

Reassemble and Test:
Disassemble the fittings and clean the unit thoroughly with cleaning solvent prior to final assembly. Blow out all debris with an air hose. You don't want any filings to be floating around in your fluid!

After a through cleaning, reassemble the jack in the reverse order that you disassembled it. Make sure you get all the fittings tight. This is where you need a big vice and pipe wrench again. Assemble the piping system for the gauge using sealing compound or Teflon tape around the threads of each joint.

Replace the fluids and replace the fill cap if you have not lost it. Remove the gauge from the fittings and pump the handle until the fittings fill with oil. You do not want any air bubbles in the system or your gauge will be inaccurate.

Finally, reconnect the gauge and apply pressure to the jack in order to test for leaks.

There were many predecessors in this project. The Tap A Jack site has a good amount of information-- thank you very much Nick. Lloyd Sponenberg also provided valuable advice on the types of fittings to use. Northern Tool Equipment is recommended as a source for some fine gauges. I need to fine

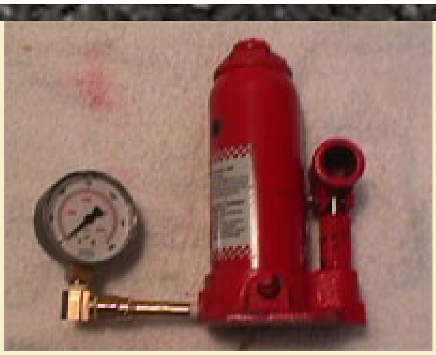

Figure 8: Reassembled jack with new gauge.

tune my jack now, possibly go to a liquid filled gauge that Northern Tool has.

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Clay Rocket Nozzles

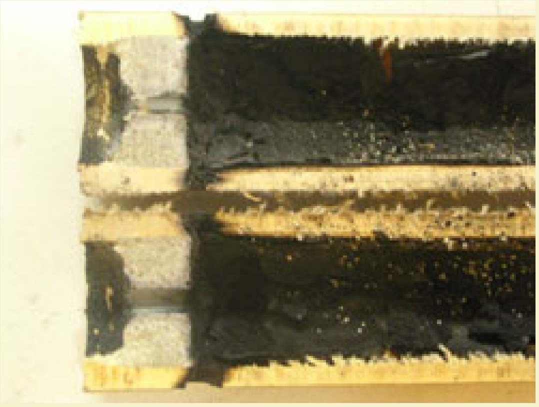

Figure 1: Burn-through just above the nozzle when the inner surface of the clay plug is flat.

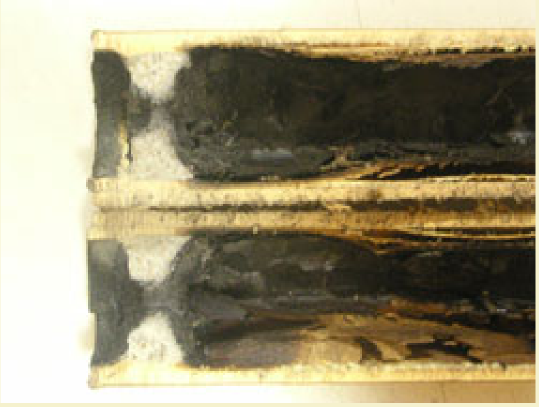

Figure 2: The same rocket with a curved inner plug surface suffered no signs of burn-through.

Introduction:

There are many options for materials to use in making rocket nozzles, and rocket builders seem to always be coming up with new nozzle formulas. The most popular and widely used nozzle material for general purpose fireworks rockets is fire clay, also known as bentonite. This is a fire proof clay that is loaded in powdered form, then rammed under pressure to form a fairly hard plug that adheres to the tube wall with enough traction to endure substantial pressure inside.

Rocket failures fall into two general categories: case failure and nozzle failure. Case failure occurs when the tube ruptures under pressure or burns through on the sides, while nozzle failure occurs when the nozzle is blown out from the tube. Widening of the nozzle hole during flight, a term called "erosion," is another type of nozzle failure that can cause a rocket to lose pressure over time. Correcting case failures is just a matter of finding a tube strong enough to hold the pressure, which usually means seeking out virgin kraft tubes or rolling your own tubes from high quality paper. Nozzle failures can be more problematic, and are often the limiting factor in how strong you can make your rocket engine. This article discusses a few common techniques for making your clay nozzles more reliable.

Nozzle Geometry

The shape of the nozzle plays a large roll in its performance. Obviously the exhaust diameter plays a crucial role in determining operating pressure, as does the thickness of the plug and the curvature on both the inside and outside surfaces. These are all easy parameters to control, but it helps to understand the effects of each.

The thicker a plug is, the more holding force it will have in the case, allowing it to withstand higher pressures and thus produce stronger rockets. However, increasing the length of the nozzle hole has the same effect as decreasing its diameter. The longer the hole your exhaust gases must travel through, the more friction there will be on the gas as it tries to escape. This extra friction will increase the pressure to a point that either the case will pop or the nozzle will blow out. This is why controlling the clay increment size is so crucial when ramming your nozzles. It doesn't take much of an increase in nozzle thickness to make the difference between a rocket that flies and one that explodes on the pad.

One trick to gaining the stronger holding force of a thicker plug without suffering the consequences of a longer exhaust hole is to make the plug concaved on one or both ends. This reduces the thickness at the center while allowing more clay to contact the case walls at the edges, as seen in Figure 2.

Another problem which can plague your rockets is having the hot gases burn a hole in the side of your driver mid-flight, which will drastically reduce the nozzle pressure and send your rocket into an arching dive. This problem can be frustrating if you don't know the simple trick for eliminating it.

Burn-through almost always occurs just above the clay plug, as seen in Figure 1. The problem is symptomatic of clay plugs that are rammed with a flat nosed rammer. What happens is that the hot gases traveling down the tube in search of an exit will slam into the flat plug and split off in all directions. Some gases will find their way out the exhaust hole, while others will bounce off the case wall before finding their way out. It doesn't take long for the continued head-on assault of the case wall just above the nozzle before these gases manage to blow-torch their way to freedom. The engine shown in Figure 1 burned with 500g of thrust for a total of 7 seconds, with the first case breech occurring only a few seconds into the burn.

The engine shown in Figure 2 was constructed exactly as that in Figure 1, with the exception of the curved inner plug surface. The curved surface tends to guide the hot gasses toward the exit hole rather than scattering them along a single plane, and eliminates the burn-through issue. The engine in Figure 2 burned for 10 seconds and doesn't show any signs of case wall erosion around the nozzle or anywhere else.

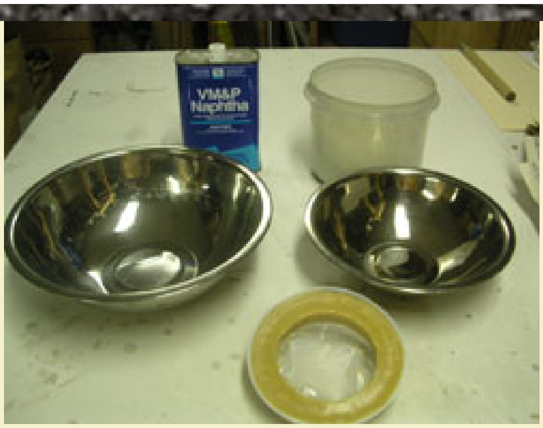
Figure 3: Supplies required for adding wax moisture resistance to bentonite clay.

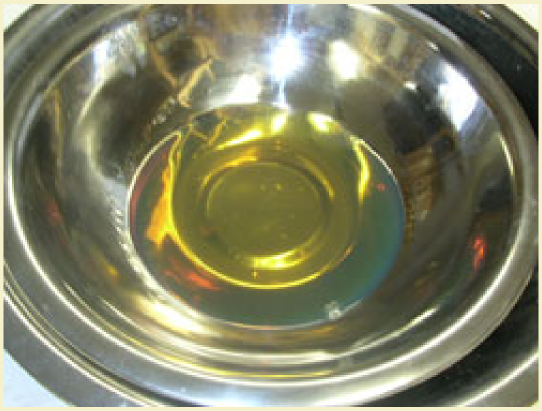
Figure 4: The yellow liquid resulting from wax dissolved into naphtha in a heated bowl.

Moisture Absorption

One characteristic of clay rocket nozzles that can cause problems is that clay absorbs moisture, which can cause it to expand slightly. If a clay nozzle expands, the nozzle hole will actually get smaller. Rockets that are built "on edge" to give maximum power for a specific nozzle size can fail with even the slightest decrease in the exhaust diameter. A rocket that works fine in one climate under one humidity level can suddenly explode on ignition when transported to a different climate, say at a distant PGI convention in another state.

Some rocket builders will carry around a set of drill bits to fine tune their nozzles at the firing location. If a test rocket blows up, the next larger size drill bit is twisted into the exhaust hole to widen it slightly. Other builders choose to avoid building their rockets so close to the edge of self destruction, sacrificing some thrust for peace of mind.

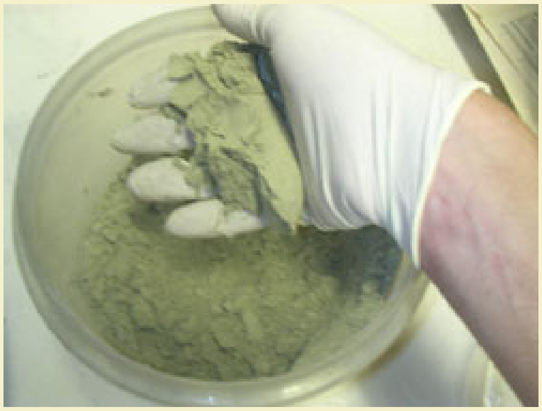
Figure 5: Working the wax solution into the clay.

Another technique you can use to battle moisture absorption is to treat your nozzle clay with a small amount of wax. This is done by dissolving about 5% wax into a solution of naphtha and working it into the clay. A good source of cheap wax is the toilet bowl gaskets found in the hardware store, which can be seen in Figure 3. A chunk of wax is cut off and weighed to get 5% of the clay weight, then dissolved in Naphtha or Coleman's camping fuel. Heat can be used to greatly accelerate dissolving the wax, but do not use open flames as you will surely ignite the flammable naphtha fumes. The best procedure is to take two metal bowls as seen in Figure 4, with one fitting inside the other, and float the inner bowl in a pool of boiled water. The solution in Figure 4 shows about 25% of the toilet wax dissolved into a yellow liquid. This liquid is then worked into the clay by hand and spread out on newspaper to dry.

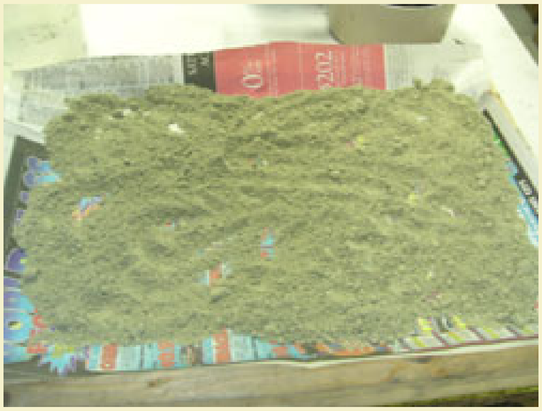

Figure 6: Drying the clay on newspaper.

Blowout Prevention

Nozzle blowouts are frustrating, and sometimes the only solution is to cut back on thrust by reducing the fuel strength or opening up the exhaust diameter. However, there are a couple of tricks to try keeping your nozzle locked into the case before sacrificing thrust.

When using recycled kraft tubes as seen in Figure 9, the case wall will actually bulge out where the nozzle is rammed. This is actually a good thing, since it makes the nozzle considerably harder to blow out. You must be sure your nozzle is not flush with the end of the tube, however, otherwise the bulge will actually have the opposite effect and make the nozzle even weaker. The nozzle must be set a little into the tube so that the tube restricts back to it's normal size just in front of the nozzle.

While recycled tubes will hold your nozzle really well, the case itself will tend to blow apart when making rockets of any respectable strength. This forces you to use harder virgin kraft or hand rolled manila tubes that can handle the pressure. Unfortunately you usually lose the bulging plug benefit when using harder tubes, unless you have a hydraulic press that can really apply some serious loading pressure. You can see that the plugs rammed in Figures 1 and 2 don't show any signs of bulging in the case wall, despite the fact that they were rammed with a 10 lb impact hammer (i.e.- the Maltese Driver Rammer shown here).

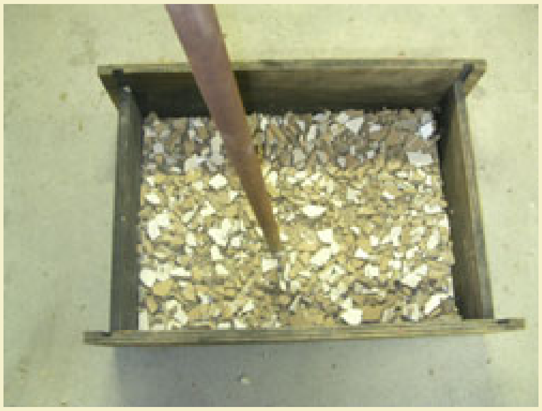

Figure 7: Grinding up floor tiles with a steel rod in a box to reduce flying shards.

Using just plain old bentonite clay in a rock hard tube will usually result in blown plugs unless you are making very weak drivers or using a very strong loading device. The trick to giving your clay more bite on the case wall is the use of a gravel like additive commonly known as grog. Grog is a type of gravel in the 25 to 40 mesh range and has the effect of biting into the paper to help the plug hold stronger. This material can usually be purchased at pottery supply stores, but you can also make your own by crushing up ceramic material like flower pots or floor tiles. In fact, I find that the home made variety actually has sharper edges and more holding strength than commercial grog.

Making your own grog is simple but not the least bit enjoyable. The process involves taking a pile of your material to be pulverized and placing it on concrete with some kind of barrier around it to reduce the amount of flying fragments. I find it easiest to stand above it with a 1" diameter iron rod and drop-mill it while wearing safety glasses and a respirator (it's a dusty process). After crushing for a while, screen the chunks out using 1/4' hardware cloth, then run the results through a 20 to 30 mesh screen. Take what falls through the screen and run it through a 40 to 50 mesh screen. What little you have left sitting on the final screen is the keeper, which you mix into your clay one part for every three parts of clay.

NOTE: grog and ceramic fragments are spark producing materials that should not be drilled through with an electric drill after the case

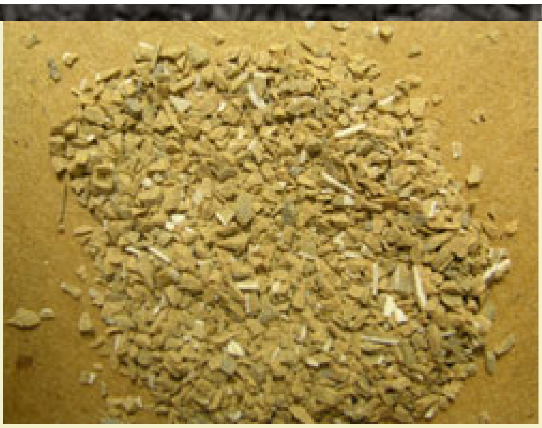
Figure 8: Close-up of 25-40 mesh tile fragments showing the sharp edges.

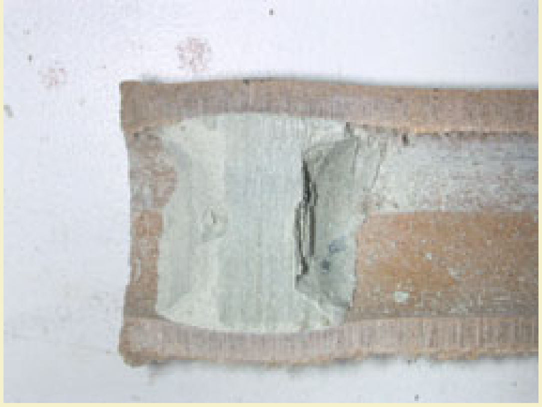
Figure 9: Weaker tubes will allow the clay plug to expand beyond the inside diameter by bulging out the case wall, which locks in the plug and makes it much more difficult to blow out.

is charged. If you need to drill out a nozzle on a loaded case, slowly hand twist the bit in the chuck of your press without turning on the power.

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Design Notes...

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Loading Pressures for Rockets

by ***Steve Laduke, John Steinberg and Kyle Kepley***

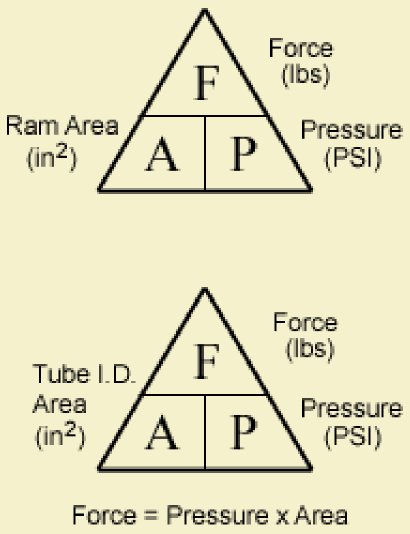

Figure 1: Pascal's law for finding the force generated from pressure over a given area.

Introduction:

This article explains how to calculate loading pressures based on the pressure reading of a hydraulic press, the surface area of the press piston and the surface area of the rammer being used to compress the fuel. An automated calculator is provided for making these calculations easier, but the reader should be aware of the relationship between pressure, force and surface area in order to have a better understanding of the variables involved.

For the solid fuel type propellants used in most hobby rocket engines, the following variables will determine the performance for a given type of fuel: the burning surface area, the nozzle or choke dimensions and the density of the fuel. The surface area is the area of burning composition at any given time during the combustion of the rocket engine. This parameter is controlled by the geometry of the tooling, so it is not an easy parameter to adjust. The length, diameter and exhaust geometry of the nozzle is controlled by both the tooling and the size of the clay increment used to make the nozzle. Because the tooling is difficult to change, the most common variables that are tweaked when developing rockets are the fuel composition and the loading pressure used to produce the engine.

To assure consistency in rocket performance, it is important to keep the powder increment size as well as the loading pressure constant. The loading pressure, combined with the amount of powder added for each pressing, determines the density of the propellant “grain," which is the name given to the solid chunk of fuel that is pressed into rocket motors. Whether one rams or presses rockets, differences in loading pressure can mean the difference between a rocket that worked during testing but then blew up on the pad during competition.

The "increment size" refers to the amount of fuel that is added for each pressing. The increment is usually measured by volume instead of weight, since it must be measured out quickly and frequently when loading a rocket. A general rule of thumb for the correct increment size is an amount of powder that compresses to a height equal to the inside diameter of the rocket you are making. Smaller increments result in more dense powder grains for a given loading pressure, while larger increments result in less density. Since a given density can be achieved through a range of increment size and loading pressure combinations, increment sizes can vary between rocket builders based on preference. However, the increment size must be noted and controlled in the same way loading pressure is controlled for producing consistent results. Any blueprint for reproducing a given rocket engine must include increment size as well as loading pressure.

While the use of pressure gauges and accurate measurements of pressures has made consistent reproduction of rocket motors easy, there are still those who practice the art and skill of ramming rockets by hand. The importance of loading force remains the same whether one rams rockets by hand, by hydraulic press or with an arbor press. Obviously, the degree of artisanship and craftsmanship required to make consistently performing devices by hand ramming is considerably greater. One does, however, after years of experience, get a “feel” for loading pressures.

Various fuels have either narrow or wide ranges of loading pressures at which performance can be assured. There is no single “correct” loading pressure for a fuel system. Rather, there is a range over which the fuel system will perform successfully. As an example, for whistle fuel, if the loading pressure is too little and the fuel is not compressed into a homogeneous grain, the imperfections in the loose material will result in its exploding. If the loading pressure is too high, the material may become brittle and crack, resulting in an explosion. Over the range of useful loading pressures, the burning characteristics will vary.

Black powder rockets also have a wide range of useful loading pressures. Greater loading pressures may increase performance by loading more fuel in the rocket. However, overly compressed black powder may burn too slowly to provide the thrust desired. Some fuels, such as strobe fuels and some color fuels, may be “dead-pressed.” In this case, once the maximal loading pressure needed to compact the grain is achieved, there is nothing further to be gained by increasing the loading pressure.

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Loading Pressures for Rockets

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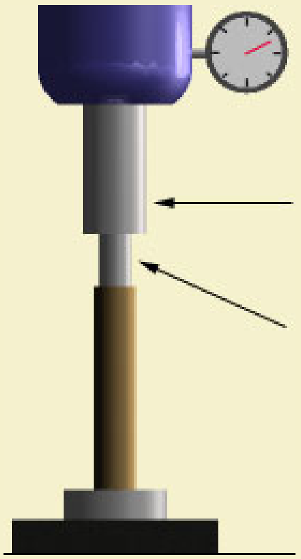

Gauge (PSI)
1588

Piston Dia. (inches)
1.77

Rammer Dia. (inches)
.875

Loading Pressure (PSI)
6500

Loading Pressure Calculator
Changing any value will recalculate all other values as you type. Gauge pressure is always solved for except in the case where the gauge pressure is being manually specified. In this case the loading pressure is solved for based on the gauge pressure specified. Note that piston and rammer dimensions indicate diameters and not cross sectional areas, allowing you to simply measure these dimensions from your tooling using a caliper and entering them directly into the calculator.

The single most important number one needs to know to manufacture a rocket is the loading pressure. The loading pressure will not, for most sizes of rocket motors, vary as the size of the rocket motor varies. For most whistle and strobe rockets (with cored propellant grains), a loading pressure of 6500 PSI may be used. For end-burning hybrid rockets, a loading pressure of 8800 PSI serves as a useful and successful approach. “End-burning,” means that the burning surface is the same as the cross-section of the rocket motor tube: there is no core in the propellant. “Hybrid” in this usage refers to the propellant composition: whistle mix with added airfloat charcoal, a hybrid fuel mix less energetic than pure whistle and more energetic than black powder.

One exception to this general rule is that for rocket motors that are smaller than 3/4" I.D., slightly higher loading pressures may be needed for best performance. For rocket motors larger than this, the loading pressures should remain the same whether one is pressing one-pound (3/4” ID), two-pound (7/8” ID), three-pound (1” ID), four-pound (1-1/4” ID), or six-pound (1-1/2” ID) rockets.

Once a new rocket system is developed for one specific size engine diameter, loading force calculations will enable one to successfully duplicate their efforts with a variety of different motor sizes. It also allows different builders using a variety of different press setups to obtain similar results regardless of differences in press sizes.

A simple formula known as Pascal's Law may be used to determine the loading pressure, as seen in Figure 1. The variables in this formula, which equate Force to Pressure multiplied by Area, are often arranged into a triangle to illustrate their relationship. One simply places a finger over the variable he wishes to solve for, and the visible part of the triangle shows the math to be performed. Variables above one another are to be divided, while variables next to each other are to be multiplied. For example, if you want to determine the Force, covering that part of the triangle leaves you with A x P. Likewise, solving for Pressure (covering P) leaves you with F/A.

An important thing to remember when working with several variables like this is to use the correct units. If pressure is being measured in Pounds per Square Inch (PSI), then the Area must be specified using square inches as well, and the resulting force will be in pounds. Do not make the mistake of using square feet or, even worse, mixing metric and English units!

The pressure gauge on your press gives you the pressure being applied to the piston head of the press, not the rammer in contact with the powder charge. Because the piston head does not have the same surface area as the rocket drift in most cases, it is necessary to perform two calculations in order to arrive at the true loading pressure applied to the powder grain. The first calculation converts the pressure on the piston head to a force value, then the second calculation converts this force back into the final desired pressure value. The following two formulas show the necessary calculations to arrive at the loading pressure:

$$\text{Force (piston)} = \text{Pressure (gauge)} \times \text{Area (piston)}$$

$$\text{Pressure (loading)} = \frac{\text{Force (piston)}}{\text{Area (rammer)}}$$

Note that these can be combined into one single formula to give the loading pressure as follows:

$$\text{Pressure (loading)} = \frac{\text{Pressure (gauge)} \times \text{Area (piston)}}{\text{Area (rammer)}}$$

Another way to think of this calculation is multiplying the gauge pressure by the ratio of piston area to rammer area, thus bypassing the need for any intermediate force calculation. The most common scenario is likely to be a rocket builder who already knows the loading pressure he wants and thus needs to calculate the gauge pressure on his press required to achieve this desired loading pressure. The equation above can be rearranged to solve for gauge pressure in this situation:

$$\text{Pressure (gauge)} = \frac{\text{Pressure (loading)} \times \text{Area (rammer)}}{\text{Area (piston)}}$$

Finally, an example from the real world to show how this all works. Using the twelve ton Harbor Freight hydraulic press, which is a popular press used by many rocket builders, the loading force calculation for a two pound rocket (7/8" I.D.) would be calculated as follows:

Desired loading pressure = 6500 PSI
Piston Area = 2.461 square inches
Rammer Area = 0.601 square inches

Gauge Pressure = 6500 x (.601 / 2.461) = 1588 psi

From this calculation one can see that 1584 psi on the press gauge results in over four times as much pressure on the motor itself! The smaller your rammer is, the more loading force you will be able to apply with your press. This is the reason small presses such as arbor presses can be used to create small rockets, even though the loading pressures are the same as for the larger rocket engines.

Now that you understand the basic relationship between pressure, force and surface area, the interactive calculator above can help you solve for the pressure values you need without ever reaching for a calculator. Simply measure the piston and rammer diameters from your tooling and enter these values into the calculator fields. Then typing in one of the two pressure values will automatically calculate the other!

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Technique...

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Whistle Rocket Fuel in Under 8 Hours

*by **Robert D. (Dan) McMurray***

From top to bottom, left to right: Nitrile chemical gloves, spatulas (large and small), 58-quart storage container, AOSafety breathing respirator, 1-gallon HDPE bucket, 20 mesh target sieve, HDPE tumbler, 500 cc HDPE measuring cup, 1-gallon HDPE bucket, 30 mesh Wal-Mart sieve, 16 quart sauce pot, 8 quart stainless steel bowl.

Introduction:
The method of making whistle mix shown here allows about 4 kilograms (around 10 pounds) of fuel to be prepared and ready for use in less than 8 hours. To improve fuel quality and decrease preparation time, this recipe uses Naphtha (e.g., Camping Fuel, VM&P Naphtha, or Mineral Spirits) to desolve the Petroleum Jelly (e.g., Vaseline.) instead of Acetone or Toluene. Naphtha solvent minimizes moisture accumulation while drying and eliminates the need to crush and/or screen the dried fuel.

Equipment List:

- Safety glasses.
- Chemical gloves suitable for handling Naphtha solvents. The "Performance Plus. Refinishing Gloves" in Nitrile or Neoprene are sold by Home Depot for about $4.00 and work well in this application.
- Breathing respirator suitable for working with organic paint solvents.
- Scale suitable for weighing chemicals.
- Two screens: one 20-mesh and one 40-mesh. Usable substitutes are available at Target and Wal-Mart in the Housewares section. An 8.5" (outside diameter) plastic framed strainer with a stainless steel screen from Target for about $7.00 will substitute for the 20-mesh screen. A 6.5" (inside dimension) all-stainless steel strainer with the name "SoftSides" on the handle and about a 30-mesh screen from Wal-Mart for about $7.00 will substitute for the 40-mesh screen.
- One stainless steel mixing bowl to withstand Naphtha solvent and hot water. An 8-quart stainless steel mixing bowl by Metro (Item No. 0065) available at Wal-Mart for about $5.00 is ideal for this purpose. This bowl is large enough to make a 4 kilogram (about 10 pounds) batch of fuel.
- Two plastic containers of one-gallon capacity or larger. To contain screening dust, screens should fit tightly onto these containers. The one-gallon high-density polyethylene bucket with 7" I.D. top made by Encore Plastics Corporation and available in the Paint department of Lowe's Home Improvement Store for about $2.00 work well with the screens mentioned above.
- A 500 to 1500 milliliter (e.g., a Pyrex beaker, plastic measuring cup, plastic tumbler) for measuring Naphtha, melting the Petroleum Jelly, and mixing the Naphtha with the Petroleum Jelly.
- Small pan suitable for heating about 2 quarts of water to warm the Naphtha and melt the Petroleum Jelly.

- **Optional:** Ball mill with two containers and two sets of media: one for fuel/catalyst and one for oxidizer
- **Optional:** A large pan suitable for heating enough water to "float" the stainless steel mixing bowl, but small enough to keep the bowl from turning over A good combination of stainless mixing bowl and large pan is available at Wal-Mart. The 8-quart stainless steel bowl identified above fits well into a 16-quart Teflon coated aluminum sauce pot by Mirro (Mfg. No. 34018) that costs about $25.00. Less expensive 16-quart sauce pots that fit the bowl are available.
- **Optional:** A container large enough to hold all of the equipment described above. A 58-quart Sterilite storage container is available from Home Depot, Lowe's Home Improvement Store, Wal-Mart and most discount department stores for under $5.00.

Ingredients for 76/23/1+3 Sodium Salicylate Whistle Fuel

Ingredient	**Small Batch (1/4 pound)**	**Large Batch (10 pounds)**
Potassium Perchlorate (K Cl O4) (oxidizer)	76 grams	3040 grams
Sodium Salicylate (Na C7 H5 O3) (fuel)	23 grams	920 grams
Red Iron Oxide (Fe2 O3) (catalyst)	1 grams	40 grams
Petroleum Jelly (stabilizer)	3 grams	120 grams
Naphtha (Petroleum Jelly solvent)	25 milliliters	1000 milliliters

NOTE: Potassium Perchlorate, Sodium Salicylate, and Red Iron Oxide must be air float powders.

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Solvent Comments:
Chemically, Acetone and Toluene are classified as "polar solvents". Acetone poses an extreme flammability hazard and a minimal health hazard. Toluene poses a severe flammability hazard and a moderate health hazard. Both evaporate rapidly; however, Acetone evaporates much faster than Toluene. Acetone mixes with water in any proportions, while only a trace amount of Toluene will mix with water.

Camping Fuel, VM&P Naphtha, and Mineral Spirits are all classified as "non-polar solvents". All are flammable; however, Camping Fuel represents an extreme flammability hazard while VM&P Naphtha and Mineral Spirits represent severe and moderate flammability hazards, respectively. All evaporate rapidly, with Camping Fuel evaporating by far the fastest and Mineral Spirits evaporating the slowest. All of these solvents pose a minimal health hazard. These solvents do not mix with water.

Sodium Salicylate is classified as a "polar reactant". Sodium Salicylate is declumped and slightly dissolved by Acetone or Toluene. Although Acetone and Toluene are not good Sodium Salicylate solvents, hard clumps form when these solvents evaporate from a Sodium Salicylate/solvent mixture. Camping Fuel, VM&P Naphtha, and Mineral Spirits do not declump or dissolve Sodium Salicylate. Hard clumps do not form when these solvents evaporate from a Sodium Salicylate/solvent mixture.

Petroleum Jelly is classified as a "non-polar reactant". Camping Fuel, VM&P Naphtha, and Mineral Spirits are excellent Petroleum Jelly solvents. Acetone and Toluene are poor Petroleum Jelly solvents.

Potassium Perchlorate and Red Iron Oxide are not soluble in Acetone, Toluene, Camping Fuel, VM&P Naphtha, or Mineral Spirits. Potassium Perchlorate and Red Iron Oxide declump in these solvents to a powder having the milled particle size.

Camping Fuel is inexpensive, readily available and very flammable, but less flammable than Acetone. VM&P Naphtha and Mineral Spirits are also readily available, but are less flammable than Camping Fuel, Acetone, or Toluene. VM&P Naphtha and Mineral Spirits are more expensive than Camping Fuel, but less expensive than Acetone or Toluene. Camping Fuel for portable stoves and lanterns is available in the Sporting Goods section of most discount department stores like Wal-Mart or K-Mart. VM&P Naphtha and Mineral Spirits are available in the PAINT section at Home Depot and most hardware stores.

Solvent	Health Hazard (NFPA)	Fire Hazard (NFPA)	Mixes with Water	Evaporation Rate (n-Butyl Acetate=1)	Sodium Salicylate (Note 1)	Potassium Perchlorate (Note 1)	Red Iron Oxide (Note 1)
Acetone	1	4	Yes	5.6	D,5	D,0	D,0
Camping Fuel	1	4	No	2.7	A,0	D,0	D,0
Toluene	2	3	0.05%	2.4	D,3	D,0	D,0
VM&P Naphtha	1	3	No	1.4	A,0	D,0	D,0
Mineral Spirits	0	2	No	0.1	A,0	D,0	D,0
Water	----	----	----	0.3	N/A	N/A	N/A

NOTE 1:
Declumping Index: A - does not declump, D - declumps to powder
Solvent Index: 0 - not a solvent, 3 - poor solvent, 5 - slight solvent

NFPA Hazard Rating:
0 - None, 1 - Slight, 2 - Moderate, 3 - Severe, 4 - Extreme

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Making Whistle Rocket Fuel...

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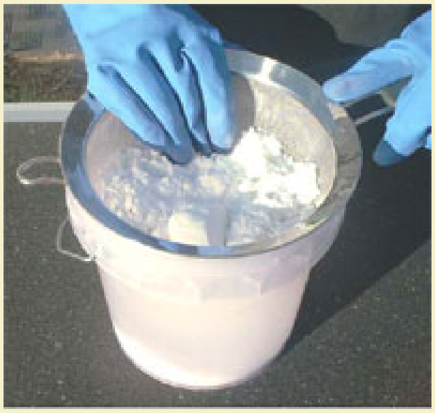

Figure 1: Screening potassium perchlorate individually into a plastic container.

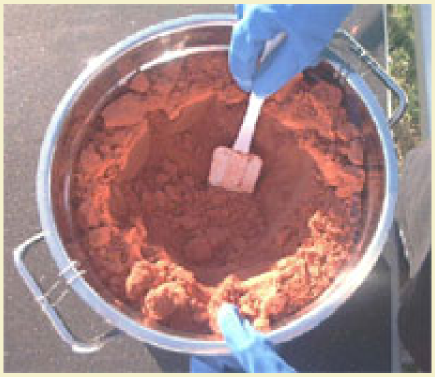

Figure 2: Stirring and drying the mixed composition over hot water.

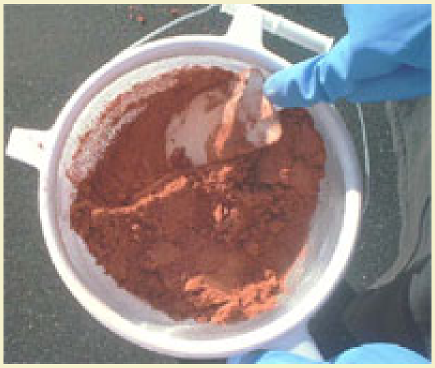

Figure 3: Screening the dried composition.

Procedure:

1) Using the scale, weigh out the Sodium Salicylate and Red Iron Oxide into the stainless mixing bowl.

Using the scale, weigh out the Potassium Perchlorate into a plastic container.

Using the scale, weigh out the required amount of Petroleum Jelly into the melting container.

NOTE: If possible, the Potassium Perchlorate, Sodium Salicylate, and Red Iron Oxide should be purchased as very fine or "air float" powders. If this is not possible, milling is required. Naphtha declumps finely powdered Red Iron Oxide or Potassium Perchlorate. Sodium Salicylate clumps must be eliminated by milling, screening, and/or adding a declumping agent.

WARNING: Do not screen, stir, or ball mill dry Potassium Perchlorate mixed with Sodium Salicylate. The dry mixture of Potassium Perchlorate and Sodium Salicylate is very static, shock, and friction sensitive. THE DRY MIXTURE IS EXPLOSIVE!!

Optional: To increase burning speed: Both the Sodium Salicylate & Red Iron Oxide mixture and the Potassium Perchlorate may be ball milled. In both cases, 8 hours of ball milling should be long enough. While being ball milled, the Sodium Salicylate & Red Iron Oxide mixture without a declumping agent will have to be broken-up periodically because it has a tendency to stick to the sides of the ball mill.

WARNING: The Sodium Salicylate & Red Iron Oxide mixture (i.e., fuel & catalyst) must be ball milled in a different container and with different media from the container and media used to ball mill the Potassium Perchlorate (i.e., oxidizer).

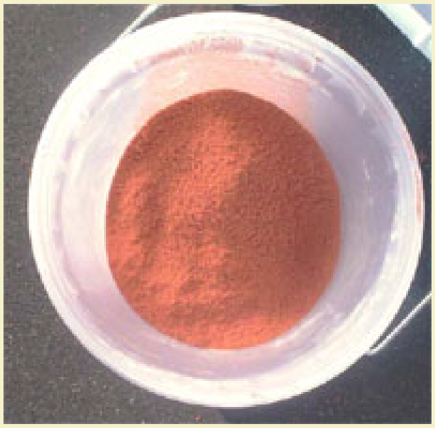

Figure 4: Dried and screened fuel ready for storage.

2) Fill the small pan with enough water to almost "float" the Petroleum Jelly melting container. Place the container of Petroleum Jelly into the water. Heat the pan, water, and Petroleum Jelly melting container until the Petroleum Jelly is a liquid. If the final mixture will be dried using the optional large pan of hot water, the large pan of water should be put on to heat at this time.

FOR THE REMAINING STEPS, WEAR SAFETY GLASSES, CHEMICAL GLOVES, AND A BREATHING RESPIRATOR FOR USE WITH ORGANIC SOLVENTS. REMOVE ALL HAND JEWELRY, WATCHES, AND BELT BUCKLES. OTHER THAN THE STAINLESS STEEL MIXING BOWL AND WATER POT, MAKE SURE THERE ARE NO METAL OBJECTS IN THE WORK AREA.

WARNING (!!!): GO OUT OF DOORS, DO NOT PERFORM THE FOLLOWING STEPS INSIDE. STAY AWAY FROM OPEN FLAMES, SPARKS, OR OTHER POSSIBLE IGNITION SOURCES. NAPHTHA VAPORS ARE FLAMMABLE.

WARNING (!!!): DO NOT PERFORM THE FOLLOWING STEPS IN DIRECT SUNLIGHT. THE STAINLESS STEEL MIXING BOWL CAN FOCUS THE SUNLIGHT AND IGNITE THE MIXTURE.

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3) Using a clean plastic container, screen the Sodium Salicylate & Red Iron Oxide mixture through the 20-mesh screen. Place the screened result back into the stainless mixing bowl.

4) Using a clean plastic container, screen the Potassium Perchlorate through the 40-mesh screen. Place the screened result into a plastic container.

5) If the Petroleum Jelly melting container is made of glass, make sure the Petroleum Jelly melting container is cool enough to keep from breaking when cold Naphtha is added.

6) Measure and pour about half of the required amount of Naphtha into the container with the melted Petroleum Jelly. Shake, stir, and/or warm the container IN HOT WATER, AWAY FROM IGNITION SOURCES, until the Petroleum Jelly dissolves in the Naphtha.

7) Pour the Naphtha & Petroleum Jelly mixture into the stainless mixing bowl with the Sodium Salicylate & Red Iron Oxide. Pour the rest of the required amount of Naphtha into the Petroleum Jelly melting container, swirl it around to rinse off the Petroleum Jelly residue, and add the rinse to the mix.

8) Using one gloved hand only, distribute the Naphtha & Petroleum Jelly mixture throughout the Sodium Salicylate & Red Iron Oxide. Scoop up the mixture, a hand full at a time, and squeeze it through your fingers until no dry powder is present in the bowl. Continue until the mixture looks like smooth tomato soup - no lumps.

9) Using your clean gloved hand, pour all of the Potassium Perchlorate into the stainless mixing bowl. NOTE: Adding Naphtha & Petroleum Jelly to the Sodium Salicylate & Red Iron Oxide before adding the Potassium Perchlorate "wets" and stabilizes the mixture, making it much safer to handle.

10) Using both gloved hands, combine the ingredients. Scoop up hands full of the mixture and squeeze it through your fingers until the ingredients are completely mixed. This step typically takes 5 minutes. The resulting wet mixture should be smooth and a uniform dark red color.

11) Remove as much of the mixture as possible from your gloves into the bowl. At this time, your gloves may be removed and set aside to dry. Most of the dry fuel can be recovered by flexing the glove material over the mixing bowl.

Using a soft plastic spatula, scrape the sides and bottom of the bowl, stir the mixture, and re-spread the mixture on the sides of the bowl. Repeat every 15 to 20 minutes until the mixture is dry and powdered.

Optional: To reduce drying time, fill the large pan with enough water to "float" the stainless mixing bowl, heat the pan of water until it boils, remove the pan of boiling water from the heat, and take it outside. Float the stainless steel bowl of wet mixture in the pan of hot water. To reduce effort and frustration, "lock" the bowl into the large pan.

NOTE: Using 1/16" stainless steel or brass welding rod, wire locks can be fabricated to secure the stainless steel mixing bowl into the top of the 16-quart sauce pot via the handles (see picture). This addition creates a tight bowl-to-pot seal and stabilizes the bowl in the water filled pot to make scraping, stirring, and spreading the mixture a lot easier.

WARNING: USE ONLY HOT WATER IN OPEN AIR TO DRY THE MIXTURE. DO NOT USE A CAMP STOVE, ELECTRIC HOT PLATE, OR ANY OTHER HEAT SOURCE THAT CAN POTENTIALLY IGNITE THE FLAMMABLE VAPORS PRODUCED DURING THE DRYING OPERATION.

Using a soft plastic spatula, scrape the sides and bottom of the bowl, stir the mixture, and re-spread the mixture on the heated sides of the bowl. Repeat until the solvent evaporates out of the mixture. When most of the liquid solvent evaporates from a large batch, final drying may be accomplished in smaller batches. The smaller the batch and the more often the mixture is scraped, stirred, and spread on the heated sides of the bowl, the less time required for drying.

12) If required, carefully screen the dried mixture through the 20-mesh screen using a soft plastic spatula.

When completely dry, the properly combined mixture is soft, fluffy, and powdered. Any lumps are small, soft, and crumble easily between a soft spatula and the side of the bowl. Except for special applications, (as in fuel to be used in small rockets) the dry, properly combined mixture should not need screening.

13) Inspect the dried fuel for white granules among the red. The presence of white granules indicates that the ingredients were incompletely mixed in Steps 8 and 10. The correction is to thoroughly "wet" the mixture with Naphtha and repeat Steps 10, 11, 12, and 13.

14) When complete, properly store the resulting powder.

WARNING: At this point, the mixture is still sensitive to static, shock, and friction (although the Petroleum Jelly has helped stabilize and desensitize the mix).

HANDLE AND STORE WHISTLE ROCKET FUEL AS YOU WOULD FLASH!

This article is a vehicle for exchanging information in the pyrotechnics craft. Readers are urged to learn and obey all laws and regulations of all federal, state and local jurisdictions and their agencies and representatives. Some information herein may contain incomplete descriptions of fireworks techniques based on the experience of its author(s) in a controlled environment with circumstances and conditions different from a reader’s. Readers must form their own opinion as to the application of this information. This information is considered documentary in nature and no opinion is given as to its suitability or use. No warranties are made either expressed or implied, including but not limited to warranties of the accuracy of the information herein.

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Tool Tip...

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Mass Rocket Launcher

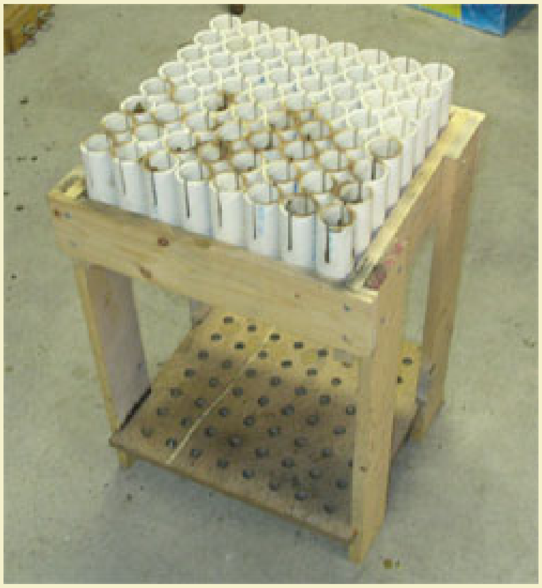
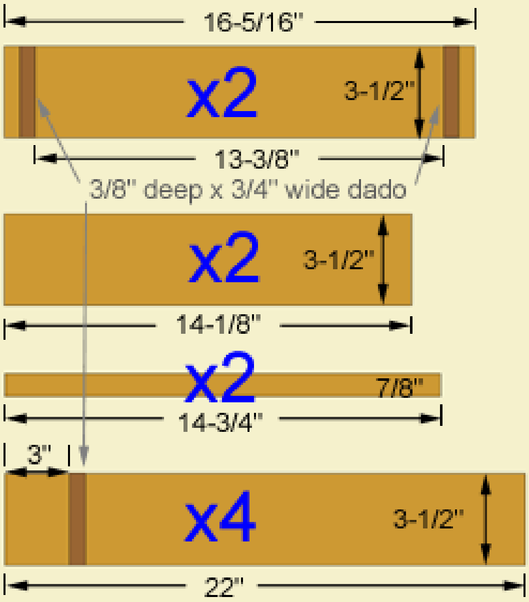


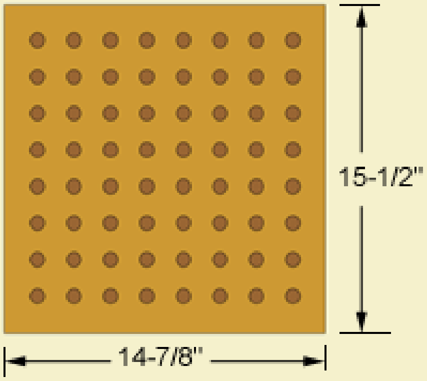
Figure 1: A configurable multi-rocket launch pad.

Introduction:
The idea of shooting many rockets in a single volley is certainly nothing new. Pyro literature as far back as Thomas Kentish's 1887 publication of The Pyrotechnist's Treasury makes mention of a wooden box with an array of holes in the bottom used to fire a "girandole of 100 rockets at once." George Weingart goes into a little more detail on a similar box in his book Pyrotechnics, with two sets of perforated plates parallel to each other such that the rocket sticks pass through both boards in order to keep them straight. In both examples the top board is covered with a layer of meal, onto which the primed rocket nozzles rest. Both designs called for a lid that could be closed over the loaded rockets in order to protect the bare meal from accidental ignition until they were ready to fire.

While the above mentioned fixtures are a good way to produce flights of rockets that occur virtually all at once, the rocket launcher described in this article is designed to allow a slower, more regulated progression of rockets one after the other. The rockets can be fired in a sequential progression, in volleys of up to 8 at a time, or in a pyramidal progression in the order of 1, 2, 3 etc. until 8 is reached. This firing order is determined by the routing of raw blackmatch fuses into slots in the sides of PVC guide tubes. Much like the fusing of a cake item, the flight of one rocket will ignite any blackmatch protruding into the rocket's launch tube when it fires. Thus any progression that can be fused into a cake item can also be duplicated with this "rocket cake" fixture. This launcher requires that all rockets be fused with black match, so most commercial class C rockets would have to be refused in order to work with this launcher.

The fixture described here was designed specifically for the 1/2" black powder rockets described in this month's Build This article, and can hold up to 64 rockets. Figure 1 shows the completed launch stand, which employs 64 segments of 6" long PVC pipe glued into a solid, removable block. The wooden





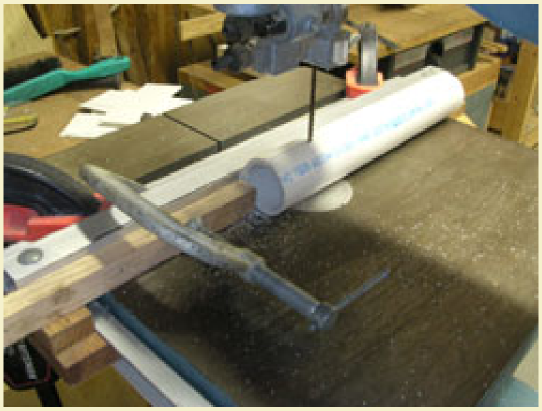


Figure 2: Cutting the passfire slots using a band saw.

stand supports this tube array such that the rocket engines will be seated about 1.5" into each tube. Because the loaded rockets actually rest on the bottom plate, an adjustable bottom plate would make for an improved design. The fixed design shown here is set for a 24" long rocket stick fastened to a 4" long engine.

Construction:
Most of the work in building this project is in fabricating the 8 x 8 grid of slotted PVC tubes. The tubes used here are 6" long segments of 370 psi white PVC measuring 1-5/8" O.D. The inside diameter doesn't matter, but the outside diameter will determine the dimensions of the box and bottom plate if your pipe is not the same O.D.

The first step is to cut all 64 segments and clean out the burrs and rough edges. Next you will need to make 2" long slots at one end, which should be roughly 1/8" wide. This is easily done if you have a band saw by using the setup shown in Figure 2. The fence is clamped so that the blade contacts the tube about 1/16" off center. A stop block is clamped 2" back from the cutting point in order to keep all cuts the same length without making measurements.

The tubes are pushed into the blade until hitting the stop block, then removed and rotated 180 degrees and cut again. This gives you both cuts of the slot, as seen in Figure 3 (blade guide raised for visibility only, don't cut with that much exposed blade). The easiest way to remove the slices of PVC is to just pull them out until they snap off, as seen in Figure 4.

Of the 64 tubes, 16 of them will need two sets of slots perpendicular to each other, while the other 48 only need one set of slots. The double slotted pipes are used as the outside rows on opposite sides, so that the fuse chain will be able to turn the corner and head back down the next row. The inside rows are just straight progressions that don't allow turns, so only one entry and exit slot is needed. While every tube could be given a double set of slots, which would result in more fuse routing patterns, this creates the added risk of gasses blowing through the slots and igniting adjacent rows out of order. Using only the minimal number of slots necessary helps insure the launch progression goes as planned.

More...

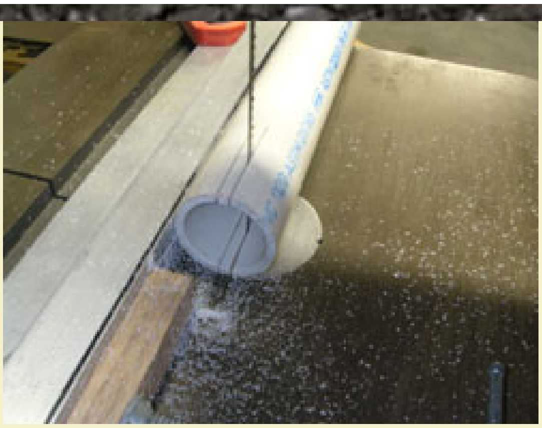


Figure 3: Fence and stop-block are used to control spacing.

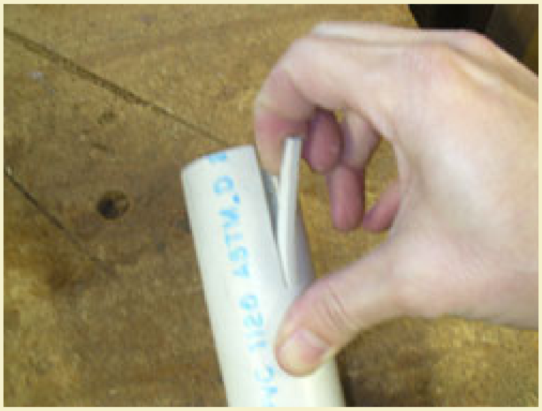


Figure 4: The 1/8" tabs are broken away by hand.

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Mass Rocket Launcher...

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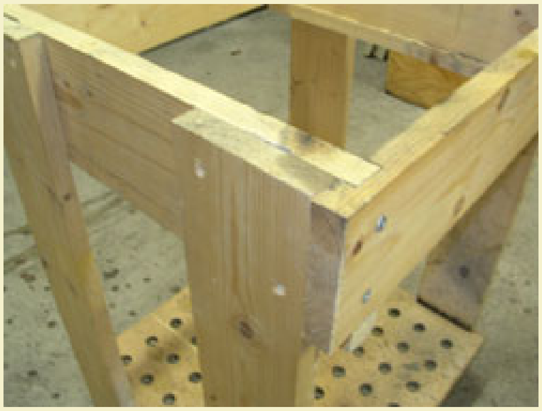


Figure 5: Joing details of the container frame.

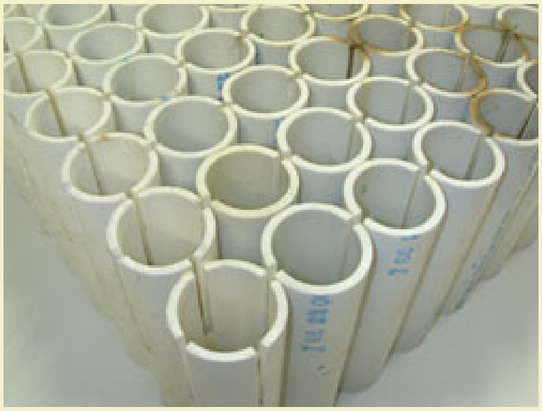


Figure 6: Closeup of passfire slots in finished tube grid.

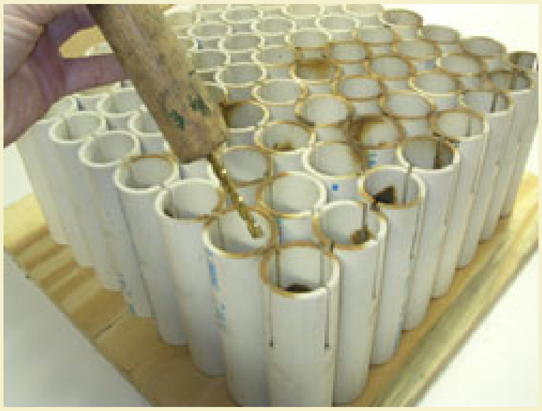


Figure 7: Using a centerpoint guide to mark the hole positions for the bottom plate.

Once all 64 slotted guide tubes are prepared, the next step is to build the box that will frame them. The box is sized so that the tubes will pack snugly into the frame, which will be used to hold them together during the gluing process. Be sure to trial-fit all the tubes into your frame to be sure they will fit before starting to glue them together.

To glue the tube array together, use PVC cement to run a bead down the side of each tube that will connect to the side of another tube. Work inside the wooden frame, placing single rows at a time. Start with a double slotted tube at one end, followed by six single slotted tubes with the slots running in the direction of the row, then finish the row with a double slotted tube. Figure 6 shows how the slots are arranged in the finished block.

Once the glued block of tubes has dried, it can be used as a guide to mark the stick holder holes in the bottom plate. Place the tube block over the bottom plate as seen in Figure 7, then use a 1-1/4" dowel with a nail or drill bit centered at one end to punch a center mark under each tube. The bottom board is then drilled out using a 1/2" wood bit at each mark, making sure not to drill more than half way through the board. These holes will keep the bottom of the rocket sticks from sliding around once the launcher has been loaded.

Figure 8 shows the bottom board inserted into the dado slots located 3" up from the bottom of each leg. The top ends of the legs are fastened to the sides of the tube box, as seen in Figure 9. The last step is to place the 7/8" wide strips of wood along the left and right bottom edge of the tube box, which serve to create a thin shelf so that the tube block can not drop through the holding frame.

Firing Configurations:
The loading diagrams below illustrate some of the possible sequences that can be created. Only half of the available launch tubes are illustrated in order to save space, but the patterns shown can be extended to use the entire tube array if you are so inclined to make 64 rockets!

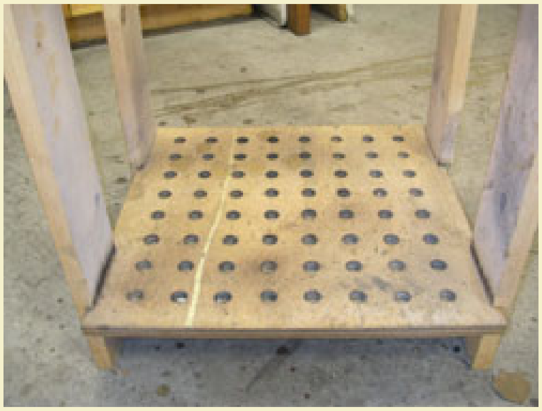


Figure 8: The stick support plate mounted into the leg channels.

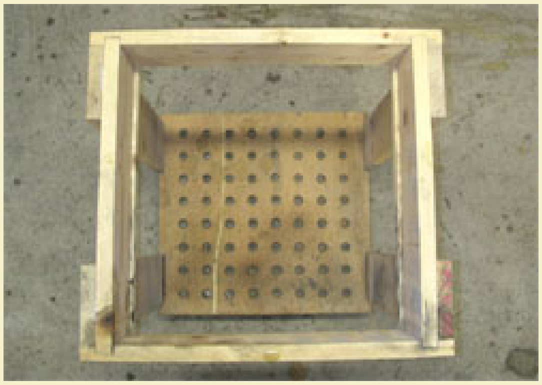
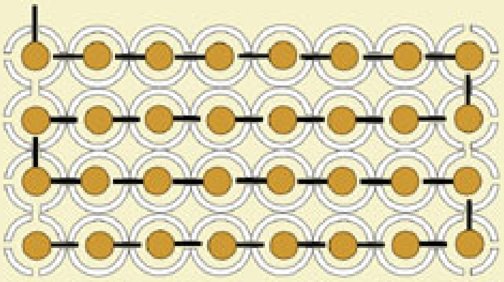
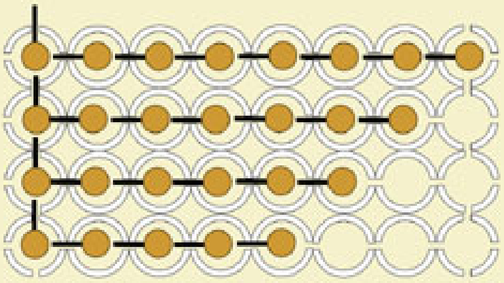


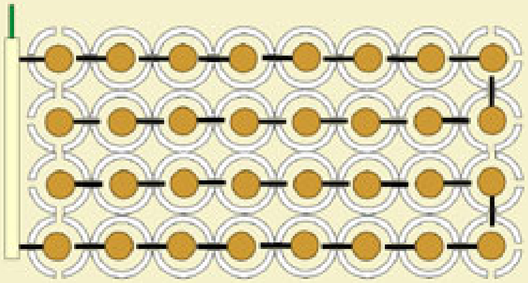
Figure 9: PVC support blocks visible on left and right edges inside the box.



A simple single-fire progression that launches rockets one after the other.



A pyramidal firing sequence that starts with one rocket, then two, then three until four is reached. This pattern is more effective when it is extended to use all eight rows, so that the progression builds up to eight instead of four. Note that empty tubes are left at the back end of the progression in order to prevent a reverse pyramid sequence at the end.



A double-fire sequence that fires pairs of rockets at once using two simultaneously ignited single fire progressions. Note that quickmatch must be used to ignite two separate chains at once. The same concept can be extended to produce as many as eight parallel rows firing at once.

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Tool Tip...

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Wooden 6 lb Stinger Missile Tooling

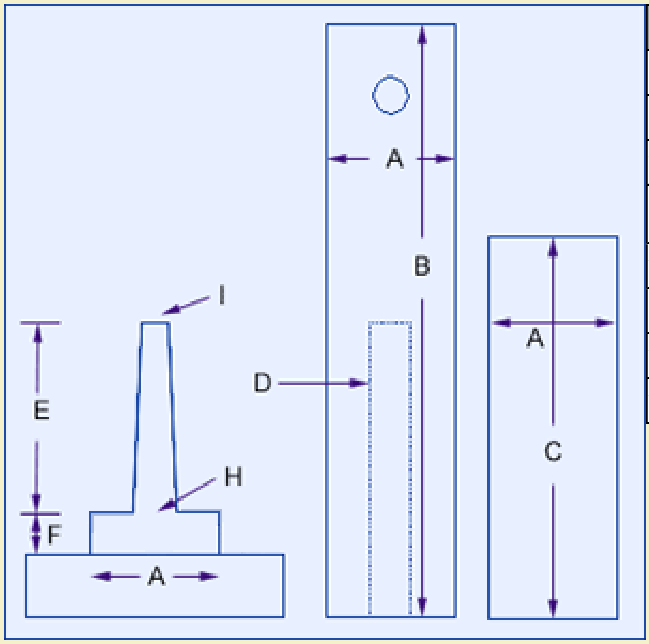

Figure 1: Dimensions for 6 pound Stinger Missile Tooling.

Description	Letter	Size
Rammer Diameter	A	1.5"
Hollow Drift Length	B	7"
Solid Drift Length	C	4.5"
Hollow Drift Hole Diameter	D	0.5"
Spindle Length	E	2.22"
Nipple Height	F	0.5"
Spindle Base Diameter	H	0.5"
Spindle Tip Diameter	I	0.3"

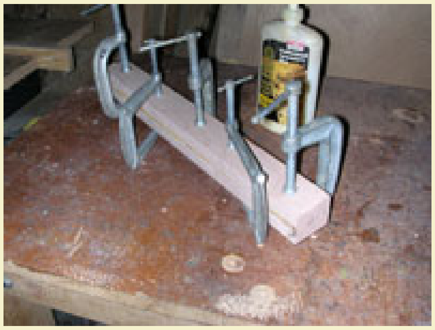

Figure 2: Laminating 1-1/2" thick stock from two pieces of 3/4" thick stock.

Introduction:

This article shows how to build the tooling required to make the 6 lb whistle rocket described here. The tooling is designed for making 6 pound stinger missile rockets, which is a type of spin stabalized rocket that uses a choked exauhst in combination with a side drilled exhaust to impart a spin to the engine as it rises. The spin actually stabalizes the engine via gyroscopic forces to the point that no stick or fins are required to insure an upward trajectory.

Rocket tooling is ideally made from non-sparking, non-corrosive metal such as brass or aluminum. A high quality version of the tooling shown here can in fact be purchased from Wolter Pyro Tools for just under $100 at the time of this writing.

While making smaller rocket spindles from wood can be quite difficult, the task becomes easier for larger tool sets. Metal rocket tooling becomes quite expensive as the rocket bore size increases, thus making wood an attractive alternative for those capable of working a simple wood lathe. The $300 cost of a typical wood lathe can be quickly reclaimed after making

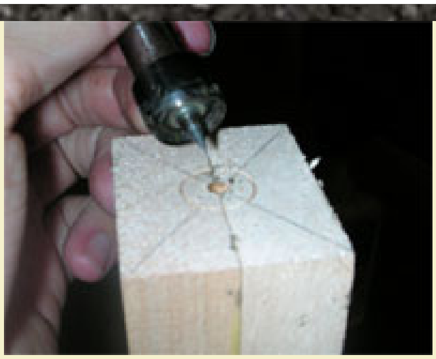

Figure 3: Punching and oiling the tailstock center.

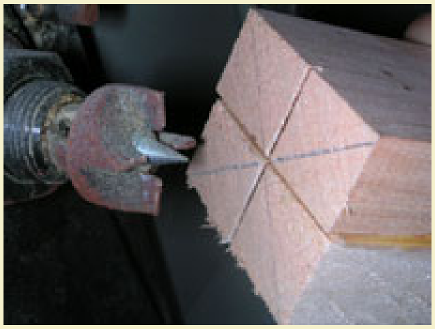

Figure 4: Notching the end to receive the spur center.

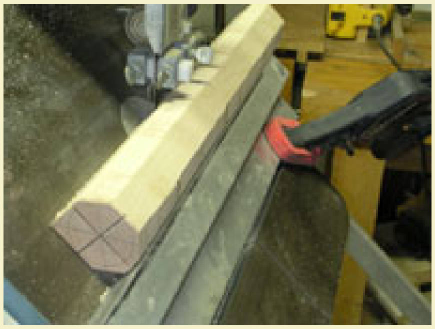

Figure 5: Reducing turning time by shaving off the corners on a bandsaw.

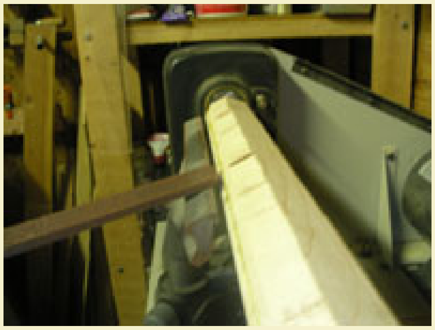

Figure 6: Proper tool rest position.

a few simple projects such as a 6" case former, 4" comet pump and this 6 pound rocket tool. Only a minimal amount of woodworking skill is required to make lathe projects, as you will generally only be making straight cylinders.

Preparing the Stock:
The wood of choice for making smooth and strong tooling is Rock Maple with the closest grain possible. Since maple is no longer sold in most home improvement stores, you will have to go to a wood specialty supplier to obtain a piece. This project will go considerably faster if you can get a piece of maple that is already turned down to a 1-1/2" dowel rod. However, this would be a lucky find so I will describe how to take standard 3/4" thick stock and make a cylinder.

Start by ripping two 2" wide pieces that are 16" long (grain running in the long direction of course). These will be glued and clamped together as seen in Figure 2.

When the glue dries, mark the center point at both ends with an 'X'. Remove the tailstock center from your lathe and use it as a punch to make the indentation shown in Figure 3. The wood piece will be spinning on this joint, so make sure you hammer it hard enough to sink in the rim of the cupped edge around the center point. Applying oil to the wood around this pivot point is highly recommended.

The "headstock" end of the work piece needs to be scored with a crossing set of cuts, as seen in Figure 4. These notches will receive the claw of the spur center, allowing it to securely grab the wood as it turns.

While the work piece can be turned at this point, removing the corners will greatly reduce the time required to achieve a cylinder and make turning much easier. Figure 5 shows one way of shaving off the corners using a band saw with the table set at 45 degrees. Draw a 1.5" circle around the center point of each end to be sure you do not shave off too much. Cutting too deep will ruin the piece and you will have to start over.

Figure 6 shows the piece chucked up in the lathe. The tool rest is placed just above the center point and is adjusted so that there is only about 1/4" gap between the edge of the tool rest and the widest part of the work piece.

A wide skewing chisel is now used to reduce the octagonal shape to a smooth cylinder. The piece is most likely too long for your tool rest to allow the entire length to be turned in one swipe, so you will need to turn down half the piece, move the tool rest and then turn down the other half.

As you approach the destination diameter of 1.5", you will need to turn off the lathe frequently and check for the correct diameter and evenness. While a caliper can be used for this, I prefer to make a half circle template out of thin plywood and use this to check sizing instead. This template can be quickly

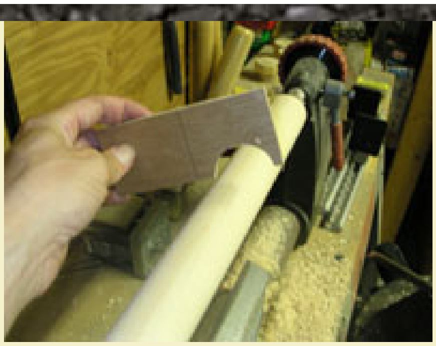

Figure 7: Using a half-circle template to check for proper diameter and eveness.

dragged down the length of the piece to scan for size inconsistency. Having an oversized region along the shaft somewhere will result in your rammer getting wedged into the rocket engine!

More...

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Wooden 6 lb Stinger Missile Tooling...

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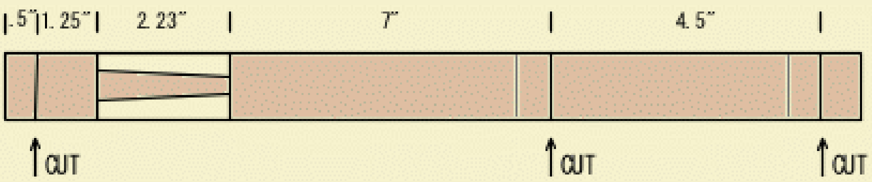

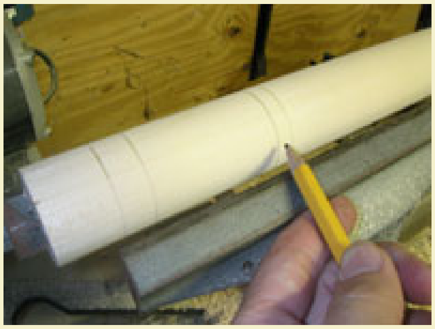
Figure 8: Marking cut points with a pencil while work rotates.

Turning the Spindle:
A stone sculptor who was well known for the realism of his work was once asked how it was that he could take a block of cold stone and turn it into the amazing likeness of an elephant. He replied "I start with the block of marble, then carefully chip away everything that does not look like an elephant."

Lathe work is a lot like this subtractive procedure, although a lot simpler than carving elephants from stone. In the case of the tooling being made here, we basically carve away everything that does not look like a rocket spindle! The remaining two components are merely cylinders that are cut from the larger cylinder to produce the two ramming drifts.

The diagram above shows how the three components of the toolset will be cut from the single piece of 16" long round stock. Having turned an even 1-1/2" diameter rod at this point, the only real challenge left is turning down the spindle.

Begin by marking five lines on the work piece as shown above. With the lathe turned off, mark each point with a pencil as seen in Figure 8. For each tick mark, place the pencil on the tool rest with the tip on the mark, then turn the lathe on and press to create guidelines that are visible while the stock is rotating. Two extra lines can be made a little to the left of the drift ends, which will indicate where to cut a small decorative channel to mark the handle end.

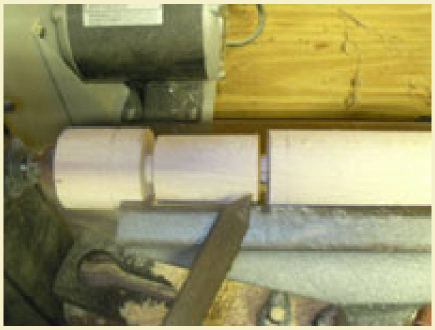
Figure 9: Turning down key spindle diameters with a parting chisel.

A parting chisel is used to quickly turn down a channel at the base and tip of the spindle. Turn both ends down to just above .5". These two cuts will also serve to face off the base of the spindle and the bottom of the hollow drift. The two cuts can be seen in Figure 9. A parting chisel has a pointed end that cuts from a sideways position instead of laying flat on the tool rest like most other chisel types. This narrow profile is designed to cut straight into the work piece as deep as required. This chisel cuts it's own clearance and will not bind, making it ideal for facing off right angles or cutting all the way through a work piece.

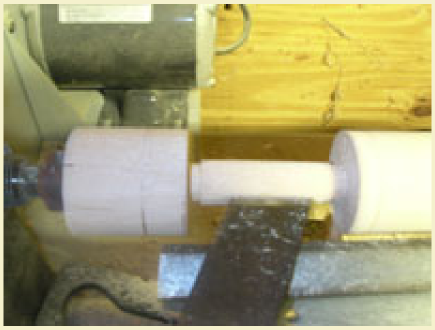
Figure 10: Removing the remaining material with a skew chisel.

Next use the flat skewing chisel to shave down the remainder of the spindle to match the diameter of the slots on either side, as seen in Figure 10. Care must be taken as the diameter nears the stopping point, as trying to take of too much material at once can cause flexing and possibly break the spindle.

Once the entire spindle is pretty near .5" diameter, use a metal file as seen in

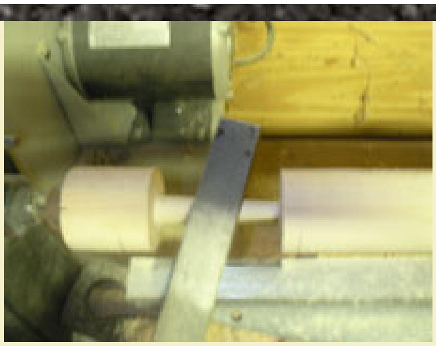

Figure 11: Using a file to produce an ultra smooth finish.

Figure 11 to fine tune the taper and give the spindle a smooth finish. One end of the file sits on the tool rest, while you other hand should hold the tip of the file to help hold it down on the workpiece. Material will be removed very slowly this way, allowing you more control as you approach the final profile of the spindle. The tip needs to be .3" in diameter, while the base needs to finish at .5". A caliper is used to verify the correct diameter of the base and tip, but there is no easy way to ensure an even taper without some kind of guide jig. You just have to eyeball the taper and hope your judgment is good!

While you have the file handy, give the edge of the spindle base and hollow drift a slight taper to help help when loading casings and inserting the rammer.

More...

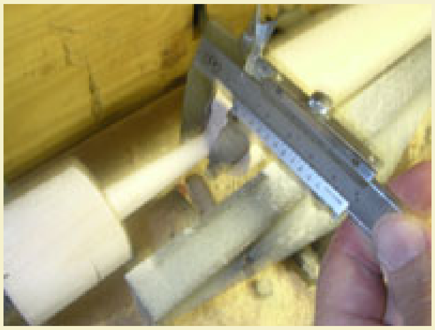

Figure 12: Using a caliper to check critical diameters near the finish point.

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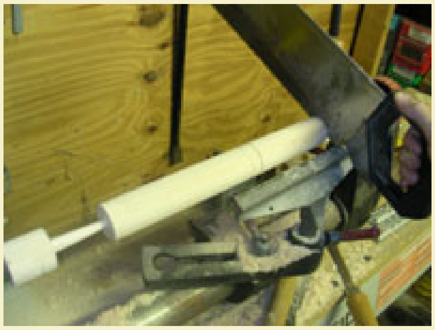

Figure 13:Using a modified hand saw to make three separation joints.

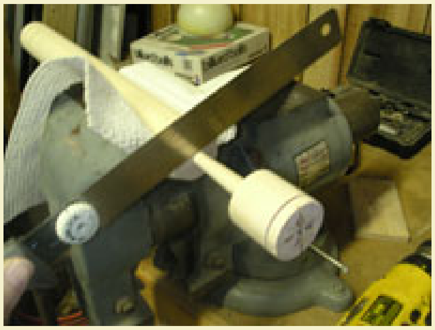

Figure 14:Using a thin kerf pull saw to cut make the final separation cuts.

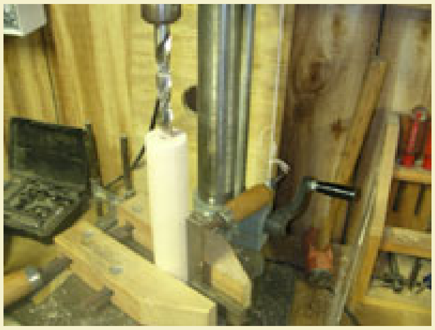

Figure 15:Drilling out the hollow drift with a 1/2" bit.

Separation and Assembly:
After the spindle is complete, the pieces are ready for separation. While the stock could simply be removed and cut into the various pieces using a table saw, cutting it on the lathe has several advantages. Separating the pieces on the lathe insures that the resulting cut is square with the sides of the rod. Separating the pieces on the lathe also makes it easy to determine the center point of the hollow drift for drilling purposes.

The pieces are not actually completely separated while on the lathe. A cut is made almost to the center, but stopping short so that about 1/2" of rod is left connecting them together. This connector piece is then cut apart afterwards using a hand saw.

While the parting chisel can be used to make the separation cuts, I prefer the use of modified hand saw that has a notch cut out near the handle. This notch allows the saw to hook onto the tool rest and thus avoid kick-back as the work piece spins into it. The saw is simply hooked in place above the guideline, then slowly brought down into the work piece while it is spinning. Care must be taken to check the depth of cut periodically to prevent from cutting too far. Otherwise a mark can be placed on the saw using masking tape so that you know when to stop.

Because the ends of the work piece are marred from the center points and are most likely not very square, both ends are lopped off and not used. This means that you will need to make three separation cuts with the saw, as seen in the illustration at the top of page 2.

Once the separation cuts are made, the stock is removed from the lathe and clamped in a vice as shown in Figure 14. Rubber no-slip matting is used around the work piece to prevent the vice teeth from damaging the finish. A thin kerf pull saw is then used to finish the separation cuts and also separate the spindle from the bottom of the hollow drift. A sander can be used to sand down any nubs left by the connector joint.

Now it is time to drill out the hollow drift. A 1/2" diameter hole must be made dead center into the bottom of the drift. The hole must be about 3" deep and be perfectly parallel with the length of the rammer. The best way to make this type of hole is to have a lathe that can be adapted with a chuck that will hold the rammer on the headstock while a drill bit is mounted in a chuck adapter on the tailstock. This way the drill bit is perfectly centered and parallel to the rammer, and it is fed into the work piece. This is standard practice on a metal lathe but not a common feature on many wood lathes. Thus, you will most likely have to do things the hard way and drill the hole using a drill press.

First you will want to center punch the mid point of the rammer where the hole is to be drilled. The lathe markings should make it easier to determine the center, as will the seam where the two boards were glued together. One key to insuring a straight hole in the rammer is to insure that the top of the rammer is truly square. Placing the rammer on end and using a right-angle gauge will reveal if your separation cut was squared off. The piece is then clamped in a wood clamp under the drill press, as seen in Figure 15. This helps insure that the rammer is perpendicular to the table. Note the angle gauge being used in Figure 15 to check for perpendicular positioning as well. Make sure everything is aligned for this critical step, then drill away!

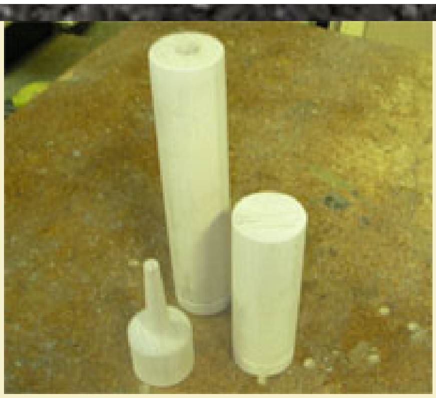
Figure 16:Finished pieces ready for sealing and hardening.

Figure 16 shows the turned pieces ready to be finished. The last bit of woodworking left is to build up a base block around the spindle piece. The nipple was cut 3/4" longer than it needs to be so that it can seat securely into a 3/4" block of wood.

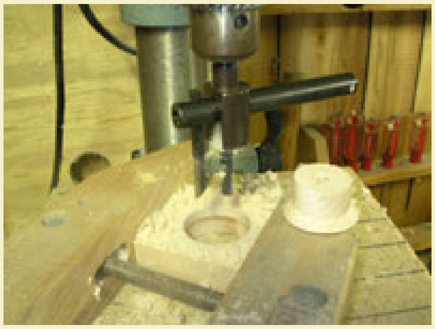
Figure 17:Using an adjustable hole cutter to make a 1.5" hole for the base.

Prepare two 2" square pieces of maple for the base. One piece will need a 1-1/2" hole drilled all the way through it. The best way to do this is to use an adjustable hole cutting jig as seen in Figure 17. This tool uses a cutting bit mounted into an adjustable arm that rotates around a center bit which drills into the wood and holds the center point. Figure 17 shows the tool along with the plug that results after the hole is cut. Since a lot of torque is involved, the wood block must be secured firmly in a clamp. Do not attempt to hold it by hand, especially since the adjustment arm of the hole cutter will be swinging around at high speeds!

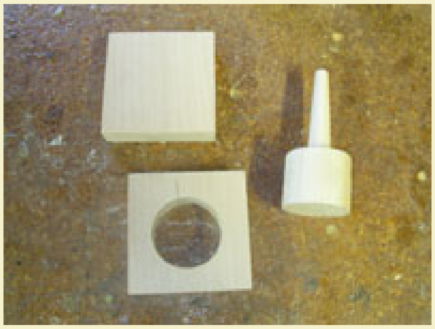
Figure 18: Spindle base parts ready for assembly.

With the hole successfully cut, you should have three pieces that will make up the spindle base as seen in Figure 18. Wood glue is applied to the inside of the hole and to the face of the solid block and the two blocks are clamped together so that their grains run in opposite directions. The spindle is inserted into the hole and four clamps are used to secure the pieces for drying (see Figure 19).

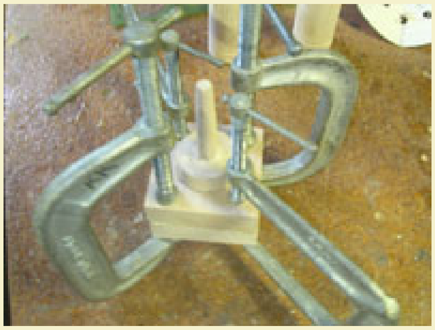
Figure 19: Gluing the spindle and two base plates together.

At this point the tooling is complete and needs the final step of water proofing. I prefer the use of marine epoxy for this step, as it is very strong, waterproof and goes on thick for a nice glossy finish. I apply two coats, sand, then apply a third and final coat.

Marine epoxy is a bit pricey and if you do not have any on hand then you really can't justify buying the pumps, brushes, gloves, resin and hardner just for this project. Polyurethane or Kryolite should also serve the purpose of protecting the wood when washing off your tooling between uses. Apply as many coats as it takes to get a smooth, glossy finish.

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Volume 4, Issue 3

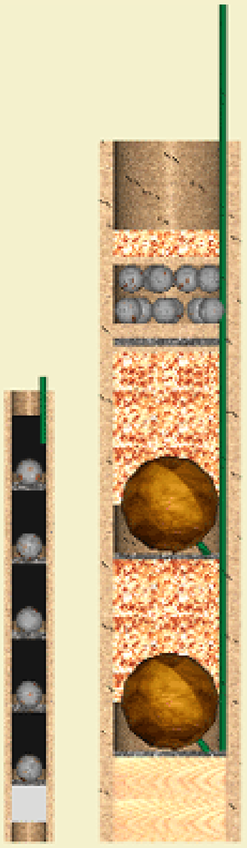
Build This...

Roman Candles

by ***Michael Fales***

Summary:
For many people, the Roman Candle was their introduction to the magic of pyrotechnics at a young age. The long wands have an almost wizard like quality as they shoot flaming, colorful balls of fire through the air one after the other. These are among some of the earliest projectile type devices produced, and the traditional construction method has changed little over the years.

Two methods of candle construction are described here: the traditional small caliber type commonly sold for consumer use, and the large caliber type that are usually Class B items used for commercial shows.



May, 2004 Issue

Build This:
Roman Candles

Design Notes:
Star Roller Design

Tool Tip:
The Ultimate Star Roller!

Accident Analysis:
Firing Range Mishaps

Class C Corner:
Killer Alligator, Absolute Pyro

Materials (small bore):

- 8" long 5/8" ID - 1/8" wall convolute wound tube
- 1/2" stars (round or pumped)
- Safety fuse (visco)
- Large wooden skewers
- Fiber tape
- 20-30 lb kraft paper
- PVA glue
- String
- 2FA black powder
- Candle delay composition
- Fire clay or bentonite

Tools (small bore):

- 5/8" x 8" long rammer

Materials (large bore):

- 2" ID x 24" long tube, 3/16" thick wall
- Safety fuse (visco)
- 2Fg black powder
- Wood glue
- Hot glue
- 20-30 lb kraft paper
- 4-1/2 cups fine sawdust
- Five 2" corrugated cardboard disks
- 1/2 cup 3/8" to 1/2" stars
- Four 1-3/4" ball shells

Tools (large bore):

- 24" long tamping stick approx. 3/4" square
- Measuring cup
- Measuring spoon set

- 5/8" rammer notched for fuse
- Non sparking ramming mallet
- Ramming block with 5/8" diameter nipple
- Funnel and measuring spoons
- 1/8" drill bit
- Electric drill
- Hot glue gun

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Roman Candles...

Page 2

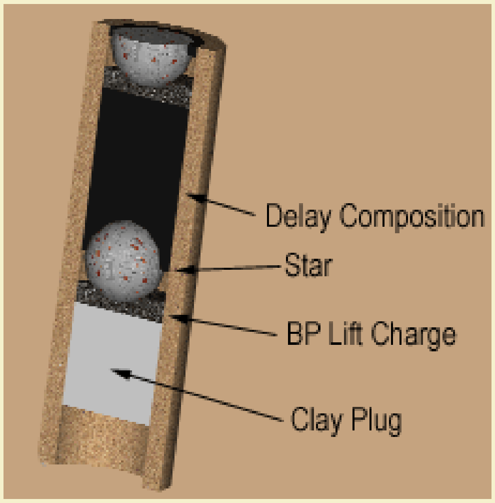

Figure 1: Components of a Roman candle shot.

Project 1: Traditional Candle

In it's simplest form, a one shot roman candle can be a small amount of lift charge at the bottom of a tube with a star placed above it. The lift charge is ignited, possibly by a bottom fused piece of black match or alternately by a piece of black match inserted into the tube, and the star is blown from the tube and burns as it travels through the air. This simple device is also commonly known as a "star tester," since it is the preferred method of testing individual stars after they are produced.

A true roman candle features multiple shots stacked on top of each other, which fire with a controlled delay between shots. The delay is created by ramming a slow burning black powder composition, known as the "delay composition," between each star/lift increment (see Figure 1). The delay comp burns until it reaches the star, which is usually a meal primed star or it can also be an unprimed star with fast burning meal rammed around the outside of it. The fast burning meal allows the flame propagation to race around the star and ignite the lift charge before the star has much time to burn in the tube. After the lift charge launches the star out of the tube, the next segment of delay composition burns until the process repeats itself.

This first candle described here is of the smaller variety most commonly seen in the class C market. There is no real perfect number of stars to shoot, but 5 to 8 shots is a good place to start. The longer a candle becomes, the harder it is to create. There is also a greater chance of the candle misfiring as its length increases. I have seen commercial 100 shot "California candles" several feet long burn erratically, shooting dozens of shots at once or just outright splitting down the side. Not only are long candle tubes hard to properly load, they are difficult to roll or find on the market.

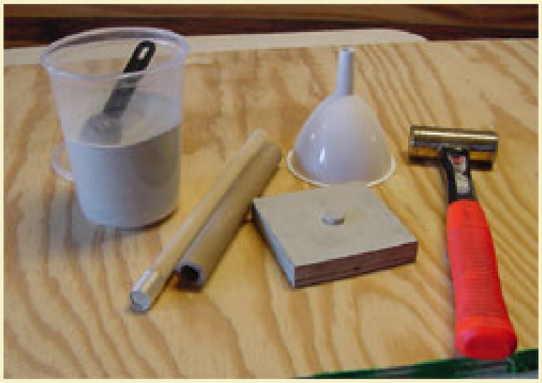

Figure 2: Materials for building a 5/8" candle.

Common sizes for commercial candles are 3/8" and 1/2" I.D. tubes. The procedure shown here is standard for candles in the 1/4" to 3/4" range, so feel free to change the dimensions. The candle shown here will use a 5/8” I.D. tube that shoots 1/2" diameter stars. Thus you will need a 5/8" I.D. convolute wound tube with a 1/8” wall thickness and a length of 8". You will also need a ramming block with a 5/8" diameter nipple protruding at least 1/4" to load the candle tube on, as seen in Figure 2. This base is not entirely necessary, as the tube can be loaded with the clay plug flush to the end of the tube, but using a nipple helps hold the tube while you are working and also results in a clay plug that is more secure and less likely to blow out during use. If you plan to make a lot of roman candles, it is even more efficient to have a long ramming block with several nipples side-by-side so that you can work on five or six candles in parallel.

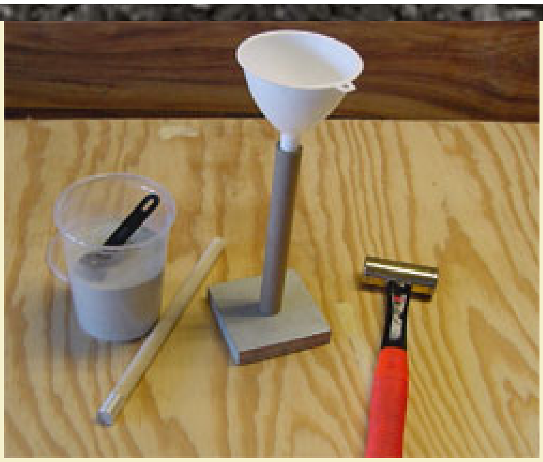

Figure 3: Using a funnel to load the clay bottom plug.

Begin by placing the tube onto the ramming block and ramming a 5/8" thick clay plug. Using a funnel as shown in Figure 3 helps guide the clay into the tube during this process. It is best to ram the plug using one increment of clay, rather than trying to build it up using several increments. A 5/8" ramming rod made from wood, brass or aluminum can be used with a brass hammer as shown in Figure 3.

Return the funnel into the top of the candle and insert 3/8 teaspoon of 2F BP lift into the tube so that it rests on top of the clay plug. This will be the lift charge for the last star that the candle fires.

Next you will add a star on top of the lift charge. The diameter of the star should be slightly smaller than the candle I.D., so that the star can drop easily to the bottom of the tube. Star selection is of your preference and depends on the use of the candle. Chinese candles use round stars, while traditional European candles employ cylindrical shaped pumped stars. If pumped stars are used, the star must be longer than the diameter of the candle in order to prevent it from flipping sideways and getting wedged in the tube during both the loading and firing process. Figure 7 shows both types of stars. A pumped star has more volume and thus will provide a large chunk of burning material, which may yield brighter colors or thicker tails. Round stars must be used for color changing effects, allowing attractive effects such as streamers to color.

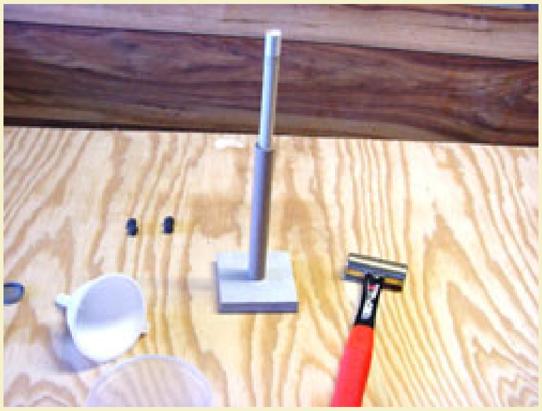

Figure 4: Ramming the clay with a wooden dowel rod.

Since most candles are designed to be enjoyed one at a time, each shot is usually a different color or effect. A candle that just shoots all one color stars would get boring by itself, but can be effective when a dozen or more of them are bundled together and fired all at once.

A common problem with small candles is the consumption of the star before the lift is ignited to an extent that it reduces the stars flight. To fix this dilemma, place the funnel back into the candle and insert a heaping 1/8 TSP of lift charge on TOP of the star. This will create a flash of fire down to the lift when the burning delay charge reaches the top of the star and will eject the star before it is consumed.

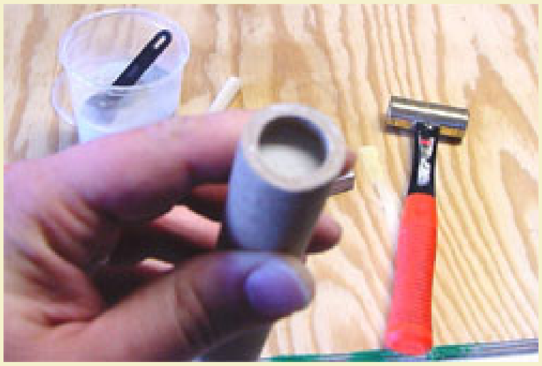

Figure 5: A recessed plug formed from the ramming base.

Next add a 1/2 table spoon of delay composition. The actual amount may vary depending on the size of the delay granules, but the rammed finished height should be 3/4" above the star. This delay composition produces a fountain like effect in between shots and provides the necessary fire block between lift charges. Use a 5/8" rammer to ram the delay with 4 to 6 light blows, not swinging the whole arm as when ramming a clay nozzle. You need to ram it hard enough to insure that the delay comp is compressed solidly and seals any gaps along the edges, but not as hard as if you were ramming a rocket or gerb. It is important not to ram too hard or you could crush the lift charge granules or crack the star.

This process is repeated, lift – star – lift - delay, until the intended number of shots has been completed. You will notice that the stars will achieve increasing height as the candle performs. This is a result of the length of the stars "mortar" increasing as each star is shot out. This effect can be compensated for by increasing the lift slightly for each star as you work your way up the candle. Some builders actually build special scoops for each shot, designed to measure out the correct amount of lift to keep all stars firing to the same height.

This is advisable if you plan to build roman candles for competition, but not necessary for just having fun.

More...

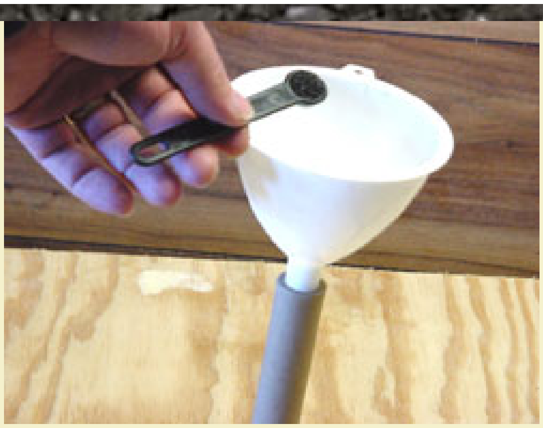
Figure 6: Loading the BP lift charge increment.

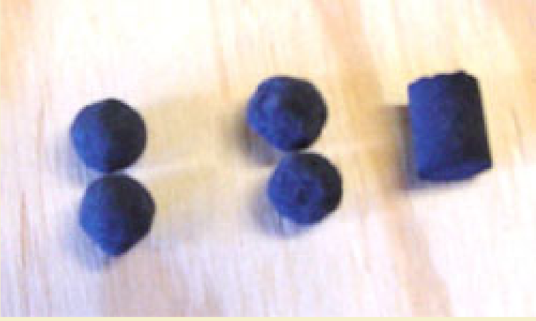
Figure 7: Two types of stars used in roman candles.

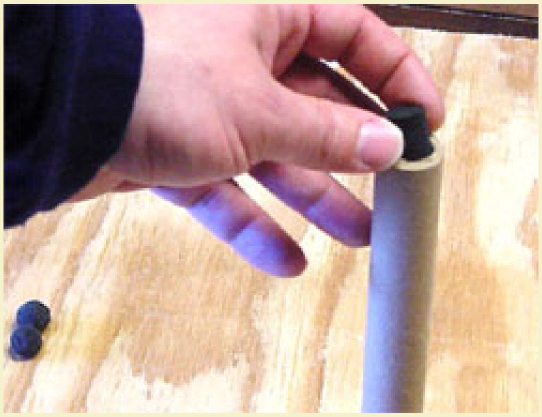
Figure 8: Inserting a star after the lift charge is loaded.

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Roman Candles...

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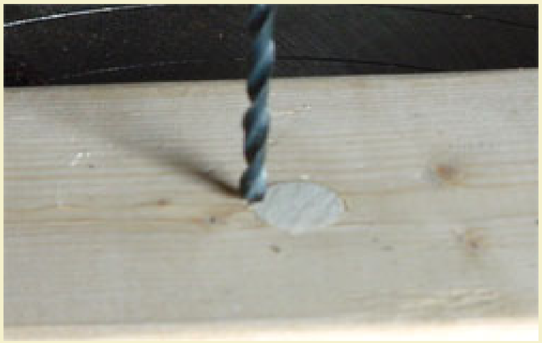

Figure 9: Notching the end of a dowel rod to make the finishing drift.

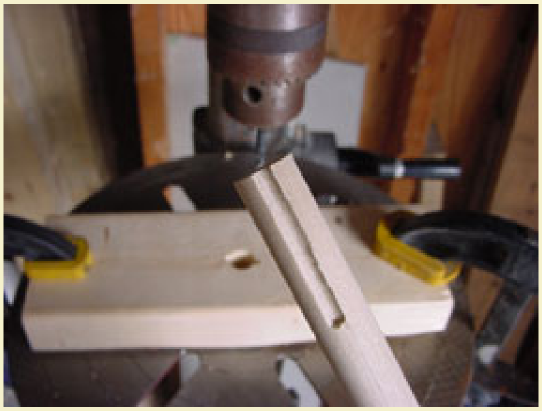

Figure 10: The notched ramming drift.

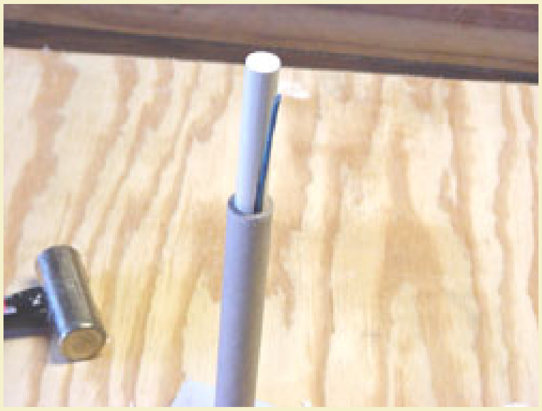

Figure 11: Locking in the fuse with the finishing drift.

While a hooked piece of fuse can be inserted into the tube above the delay comp to fuse the candle, a more secure fusing method is to ram the fuse in with the last delay increment, thus locking it in place. To do this, a special notched rammer must be fabricated as shown in Figure 10. Special thanks to Dan Williams for this great tool tip. This drift can be created using a drill press as seen in Figure 9. Clamp a scrap piece of 2x4 lumber onto the drill press table and drill all the way through with a 5/8” bit. Make sure the hole in your table will accept a bit of 5/8” diameter before drilling! Insert the 5/8” dowel stock from the bottom through the hole until flush with the top of the 2x4 material. Do not cut the dowel before drilling as it makes it easier to hold in place while drilling and to remove from the lumber when finished. Using a 3/16" drill bit, adjust the workpiece so that the hole will be drilled right at the edge of the dowel as seen in Figure 9. Lock the table in place and hold on to the dowel below the press table. Drill into the dowel and lumber 2” deep. Remove the dowel from the lumber and cut to length – approximately 5 inches.

After ramming the final increment of delay, insert enough loose delay composition to create a 1/2” of rammed comp and stick a piece of safety fuse to one side and into the loose delay charge. Slide the drift into the tube placing the safety fuse into the void, then ram as before.

Finish the candle by gluing two turns of 30 lb kraft around the top and twist the paper down onto the safety fuse. This nosing will protect the delay from igniting from sparks of adjacent fireworks.

Firing the Candle

A Roman candle should always be lit with caution. It is ironic that roman candles are commonly thought to be safe to fire while holding them in your hand, since they are more prone to malfunction than many other pyrotechnic devices. Any gaps or voids in the delay comp can cause a rapid fire burst of all shots at once, driving the candle out of your hand. The same phenomenon can also cause the candle to explode if the tube wall can not handle the pressure of all shots trying to fire at once. Poorly made candles have also been known to blow out the bottom plug and send flaming balls out the tail end at the same time, which could cause serious injury if held out in front of your body. Hot dross from the burning delay comp can also drip down and burn holes in your shoes, pants and skin. Regardless of what you've seen or what you did as a kid, Roman candles are not devices that can be safely held in your hand during use.

With that said, a way must be found to secure your candle in a vertical position without risk of it tipping over during the display. Shoving candles into the ground can be a chore or can even bend and destroy them. Spent class C tubes or pipes rammed into the ground work well as holding containers. A 5 gallon bucket full of sand allows the candle to be easily inserted and provides a heavy, stable base as well. Another method is to tape a large wooden skewer to the side of the candle so that it may be easily anchored into the ground. Place the skewer so that the blunt end rests near the top of the candle and the point extends well beyond the bottom, as seen in Figure 14. Wrap a couple of turns of strapping tape around the candle and skewer both at the top and bottom. Note that this does not work in well in frozen ground and is also not stable in overly soft ground.

More...

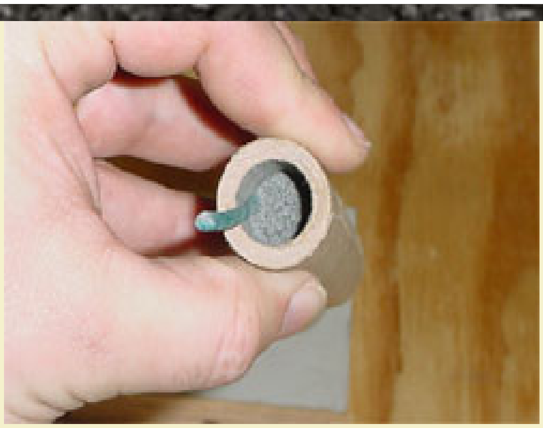
Figure 12: Top view of driven in fuse.

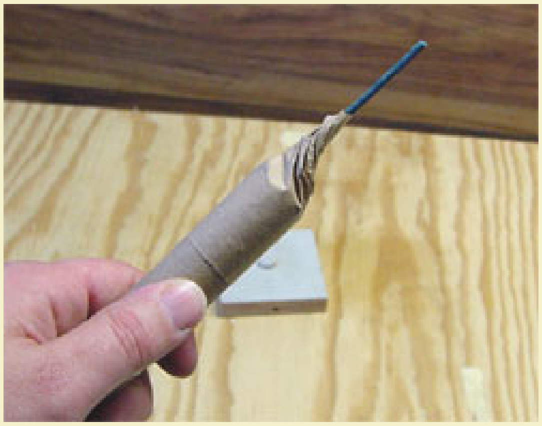
Figure 13: Nosing paper applied.

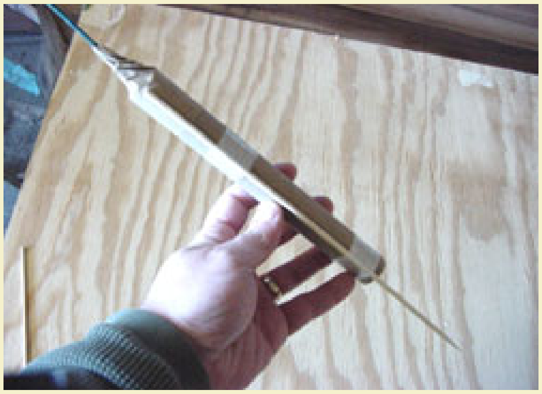
Figure 14: Attaching a stake for securing the candle during use.

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Roman Candles...

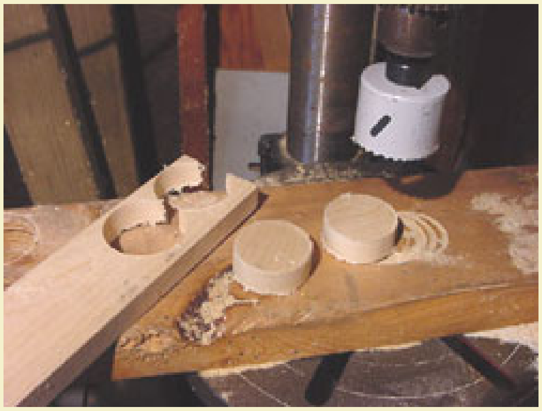

Figure 1: Using a hole saw to cut 2" diameter end plugs.

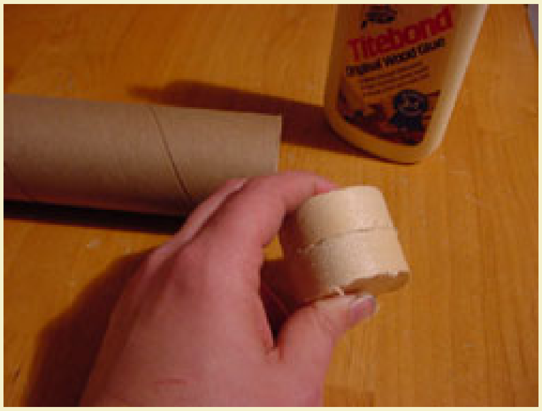

Figure 2: Gluing two 3/4" thick plugs together to form the end plug.

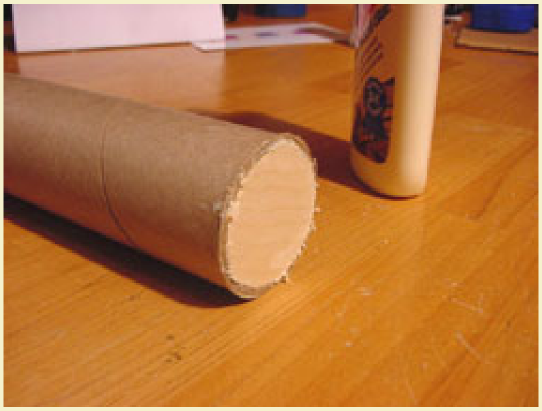

Figure 3: End plug glued in place using wood glue.

Project 2: Large Candle

While the traditional method of candle construction previously described works well for smaller diameter candles, it poses problems with larger diameter candles. As the diameter increases, so does the volume of delay comp required to pad between the stars. This not only increases cost in terms of materials used, but also puts greater demands on the roman candle tube, which must stand up to the continuous burning of delay comp for the duration of the candle without the tube wall burning through. Larger candles also tend to use insert devices such as salutes, crossettes, small shells and other devices that may become damaged by a delay comp burning around the outside of them.

For larger candles, delay composition is not used between shots and timing is done with fuse. Various methods exist, but they all have one concept in common: bulkheading between each shot with a light-weight material to seal against gas leaks and then using some kind of fuse as the timing mechanism.

The candle described here uses one continuous piece of visco type safety fuse to control the timing and ignite each shot, with a fine sawdust bulkhead between shots. The absence of a delay comp allows us to use a much thinner tube wall than would otherwise be required. The tube used here is a 24" long spiral wound tube with a 2" I.D. and a 3/16" wall. Because this candle will be shooting 1-3/4" diameter insert shells as the shots, the tube must be strong enough to handle the lift force. Be sure to test your own tubes by firing a few 1-3/4" shells from them before making this type of candle.

To plug the bottom of this tube, you will need to cut two 2” circles of 3/4” wood and glue them together cross grained to form an end plug. A 2-1/8” hole saw with the drill bit removed from the arbor will produce the appropriate sized wooden plugs, as seen in Figure 1. Apply wood glue to the inside bottom of the tube and insert the wooden plug flush with the bottom. Small finish nails or staples can also be nailed through the tube wall to secure the plug even further. Let the glue dry before proceeding to the next step.

Next you will need to cut a length of safety fuse 6” longer than the candles’ inside length and bend the last inch at a right angle, as seen in Figure 4. Insert the bent end of the fuse into the tube all the way down to the wooden plug. Inserting a notched cardboard disk down over the bent piece of fuse helps to secure the fuse in place and prevent it from getting pulled out of place during assembly. The entire construction of the candle from this point on must be done vertically to avoid shifting the components.

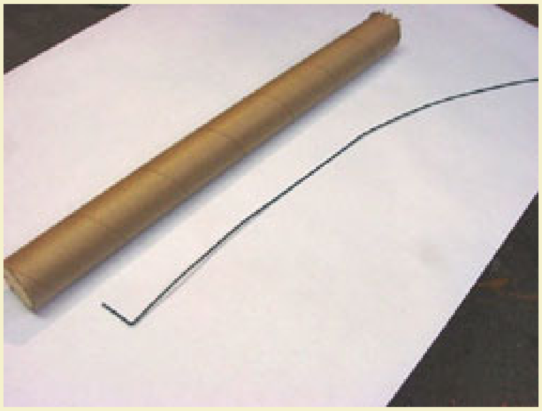

Figure 4: A long length of visco cut a few inches longer than the candle tube.

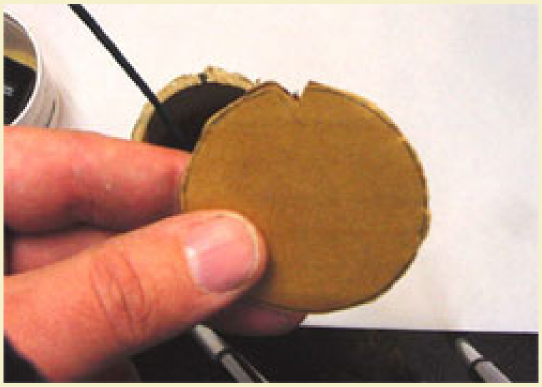

Figure 5: Inserting a notched cardboard disk on top of the visco "hook".

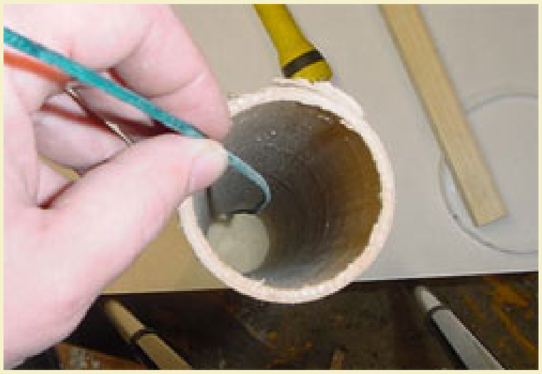

Figure 6: Tube is fused and ready to load.

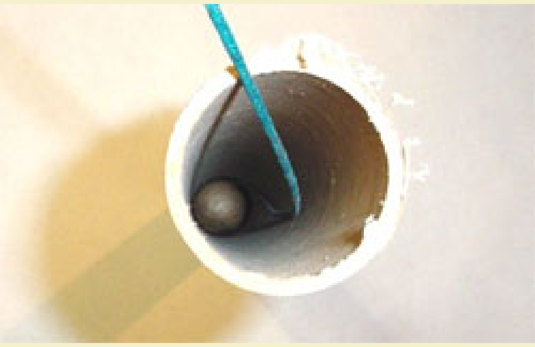

Figure 7: A 1-3/4" ball shell is loaded above

Pour 1-1/2 tea spoons of 2FA BP for lift into the tube, shaking the tube gently from side to side to level the powder grains. Push the fuse to the side of the tube and drop one 1-3/4” shell into the tube so that the time fuse of the shell rests to the side and contacts the lift powder as seen in the cross sectional diagram on the title page of this article.

After loading the shell, pour in 1/2 cup of sawdust on top of the shell. A finely powdered sawdust is highly recommended for its ability to seal well against gas leaks. Using granular sawdust or chips can cause the first shot to ignite all shots at once, which will likely detonate the candle and throw live shells in all directions.

Insert a wooden tamping stick and consolidate the sawdust down flat making sure to ram the corner of the stick next to the fuse from time to time while tamping. Drop down another 1/2 cup of sawdust and tamp flat as well. Be sure to concentrate around the fuse area to maintain a tight fire block. The sawdust should compress to 4 inches above the lift charge to give the correct delay time. Figure 8 shows the completion of the first shot after the sawdust has been added.

Repeat this process again for each of the remaining three shell shots, placing 1-1/2 teaspoons of 2FA BP for the lift on each one. When pouring the lift down on top of the sawdust delay, lean the tube slightly toward the fused side in order to create a slight buildup of lift around the fuse area.

Once all four shells are loaded, a mine will be added as the first shot in the candle. The mine will create a nice starting effect and give the candle some variety. Note that mines should not be used for effects further down the candle as the mortar length will be to long.

Cut four 2” disks out of corrugated cardboard and run a bead of hot glue on one disk and stack another on top to create the piston for the mine. Snip a small piece out of the side of each disk to allow room for the fuse, as seen in Figure 5.

The mine will use 1-3/4 teaspoons of 2FA BP lift and will create more pressure on the sawdust below it than the other lift charges will. To help protect the last sawdust delay under the mine from this increased back pressure, slide a single cardboard disk into the tube before loading the lift charge for the mine. Align the snip in the disk with the fuse and press it down into the candle firmly on top of the sawdust. It is easiest to press in the disk in level with your hands and then slowly push on the disk with as large of stick that will fit in the tube to avoid flipping the disk. This step may not be necessary, but it doesn't take much time and is a bit of insurance on a device that has a lot of time invested in it already.

Pour in the 1-3/4 teaspoons of 2FA BP lift charge for the mine, followed by the piston disk. If the piston disk fits real tight or you are worried about the stars burning for too long before the lift charge ignites, you can perforate the piston disk as seen in Figure 9. The holes in the piston will allow quicker fire transfer to the lift charge.

Measure out 1/2 cup of the stars of your choice and place them the lift charge.

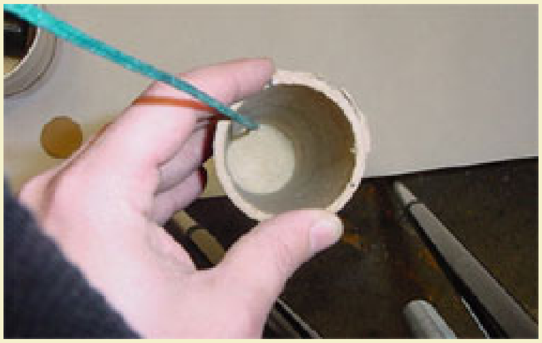

Figure 8: Sawdust is firmly packed around the shell to a thickness of 4" above the lift charge.

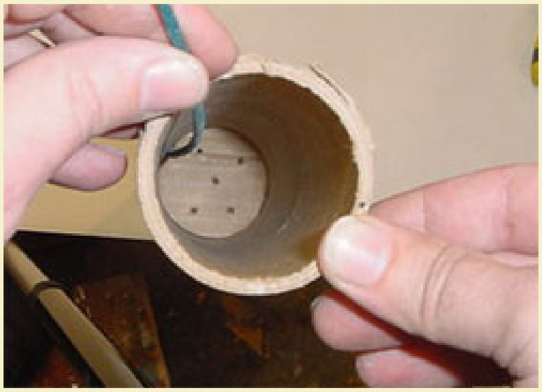

Figure 9: Placing the lift disk over the BP charge on the final mine shot.

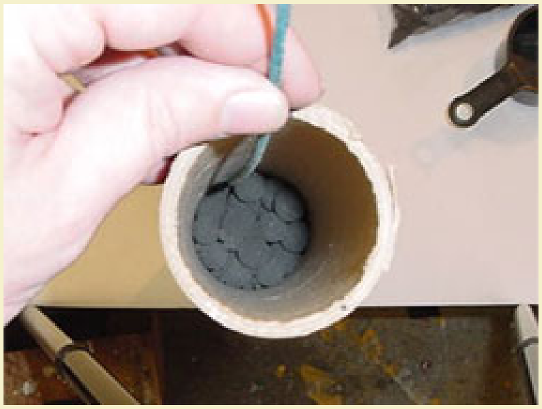

Figure 10: Mine stars placed on top of lift disk.

inside the candle on top of the piston. 3/8” to 1/2" stars are a good size to use depending on burn rate. The stars seen in Figure 10 are 1/2” stars of Slow Gold formula rolled over 1/4” crackle cores. These stars are chosen for their tail effects which make a full mine that appears to be larger than 2”.

Drop in 1/2 teaspoon of 2FA BP on top of the stars and shake down to integrate it into the mine. Place the remaining single cardboard disk into the candle and press down onto the stars, as seen in Figure 11.

The fuse extends up the candle for several more inches which could cause premature ignition on its way down the tube. Protect the stars from sparks by placing 1/4 cup of sawdust on top of the cardboard disk and tamp flat. Bend the fuse over the top and secure to the tube with tape or pasted paper. This last step is an important precaution to insure that the fuse can not be yanked sideways, which could loosen the sawdust around the fuse and create an air gap that would either fire all shots at once or, more likely, detonate the candle.

The candle is finished by gluing a couple protective layers of thin kraft paper over the top as seen in Figure 13.

Firing the Candle

As previously mentioned, Roman candles should not be held in your hand. This is ESPECIALLY true of larger candles such as this one, which would cause serious damage were anything to go wrong. The kickback force of large candles will also blow them right out of your hand were anyone foolish enough to try such a stunt. This candle is best fired by dropping it into a 3" mortar that is buried in the ground, then retiring behind a safe barricade.

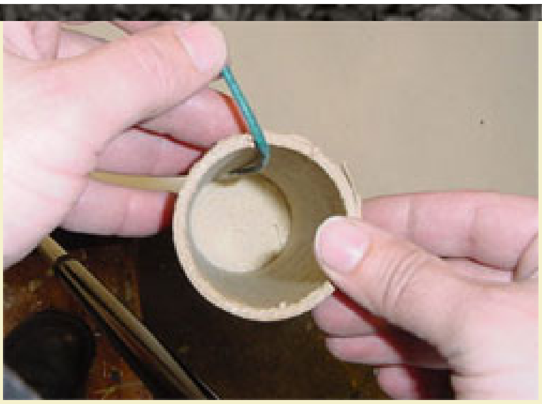

Figure 11: Sawdust packed on top of mine stars.

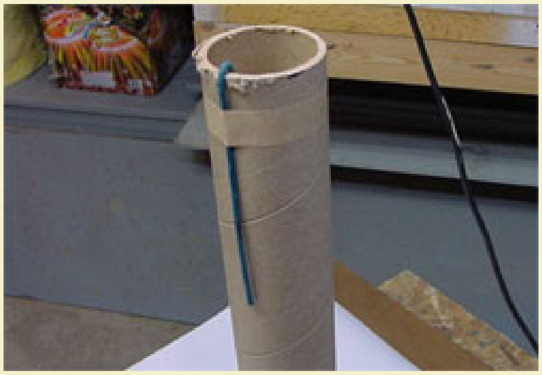

Figure 12: Securing the visco to the candle.

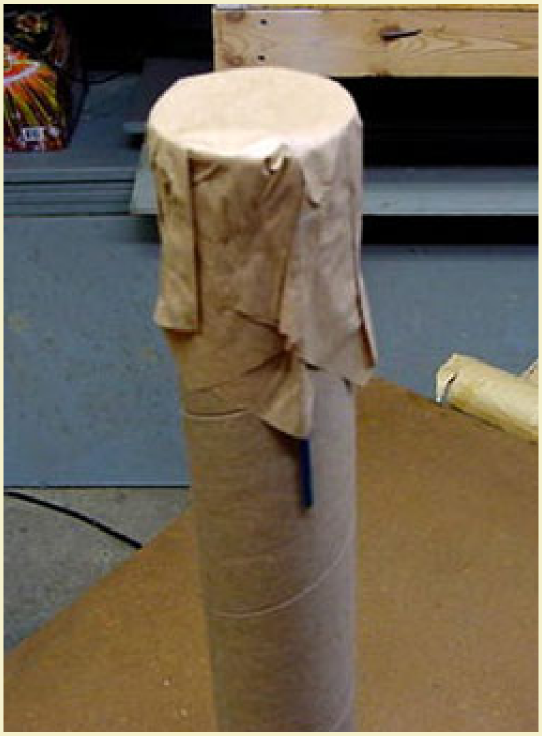

Figure 13: A protective cover pasted over top the candle.

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Technique...

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Coating Magnesium, Part I

Introduction:
Powdered magnesium is one of the most reactive metals used in pyrotechnics. Magnesium is vulnerable to attack by many salts, sulfur compounds, acids and even water. Even boric acid, which is commonly used to protect aluminum in the presence of nitrates, will react with magnesium. Unfortunately, some of the more active reactions occur with oxidizers and color agents commonly used in pyrotechnic formulas, such as copper sulfate, ammonium perchlorate, sodium bicarbonate, potassium chlorate, potassium perchlorate, potassium nitrate and strontium nitrate to name just a few. The perchlorate and nitrate reactions are not quite as strong at room temperature, and keeping the materials very dry helps slow down reactions as well. However, even these less reactive ingredients have the potential to cause problems if the material is to be stored for very long.

Magnesium is also among the most expensive metals used in pyrotechnics, especially for the hobbyist trying to obtain the material in small quantities. Recent shipping restrictions in the U.S. have made magnesium particularly difficult to obtain. The few hobby suppliers that do carry the desired atomized magnesium are forced to dilute it with 50% of useless magnesium turnings in order to ship it. Thus the cost of an already expensive metal is effectively doubled by yet another arbitrary and futile regulation in the name of "safety."

So with the high cost and problematic reactivity of magnesium, why does anyone use it at all? Well, like every other hazardous or expensive chemical that tempts us with the promise of better quality effects, magnesium offers a purity and brightness of color that is unmatched by any other metal fuel. Adding even a small amount of magnesium to an existing color formula can often create added brilliance without washing out the color quality any noticeable amount. Where colored strobes are concerned, magnesium in combination with ammonium perchlorate produce the best and brightest colors possible. For colored flash formulas such as those used in Maltese Beraq formulas, magnesium is a critical component that can not be substituted by any other metal without total color loss.

Assuming you can get past the financial barrier to using magnesium, the next step is to overcome the reactivity problems by coating it with a suitable protective barrier. There are several materials available for doing this, each with different levels of protection. The three most common coatings are shown in the table below, which indicates the level of protection provided by linseed oil, paraffin and potassium dichromate for a group of the most problematic chemicals.

Protection of Magnesium Coatings
(tested in wet state at room temperature)

	Uncoated	Linseed Oil	Parafin	Potassium Dichromate
Water	x	o	o	o
Ammonium Perchlorate	xxxx	xxxx	xxxx	s
Potassium Chlorate	xxx	o	xx	s
Potassium Perchlorate	xxxx	o	xx	s
Barium Nitrate	xxx	o	s	s
Strontium Nitrate	xxx	o	s	s
Potassium Nitrate	xxx	o	s	s
Sodium Nitrate	xxx	o	o	s

o: No reaction occurs.
s: Slight reaction, but useful in practice.
x: Attacked slowly.
xx: Attacked considerably.
xxx: Attacked actively.
xxxx: Attacked violently.

Source: *Fireworks, Art, Science and Technique* by Takeo Shimizu, Ph.D.

It is seen that Linseed Oil would be the perfect all-purpose coating were it not for the one pesky case of ammonium perchlorate. Potassium dichromate is the only coating that will protect against contact with ammonium perchlorate. Since the color and strobe formulas containing magnesium in combination with ammonium perchlorate produce the best color purity available, you will eventually find yourself wanting to use them when producing the best possible effects. For all other cases it is better to coat your magnesium with linseed oil, if for no other reason than to avoid the toxic hazard of working with potassium dichromate.

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Coating Magnesium, Part I...

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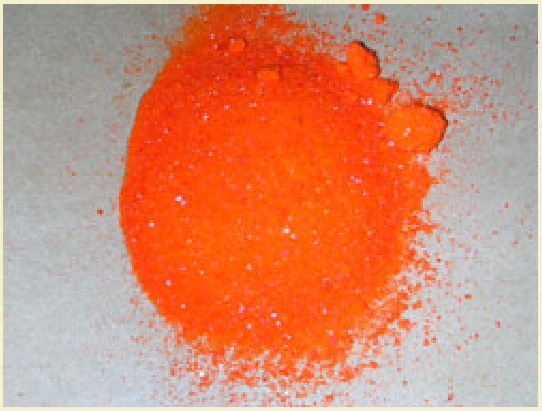

Figure 1: Close-up of potassium dichromate crystals.

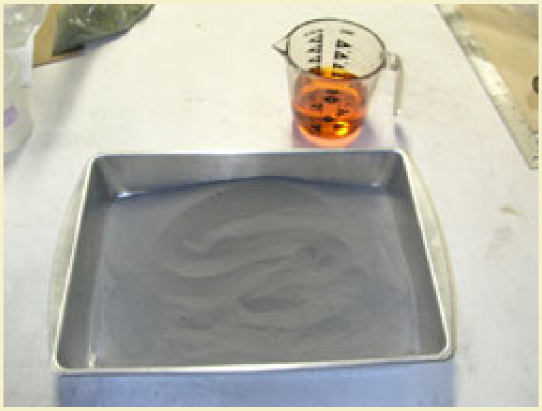

Figure 2: 1000g of magnesium with 10 oz of dichromate solution.

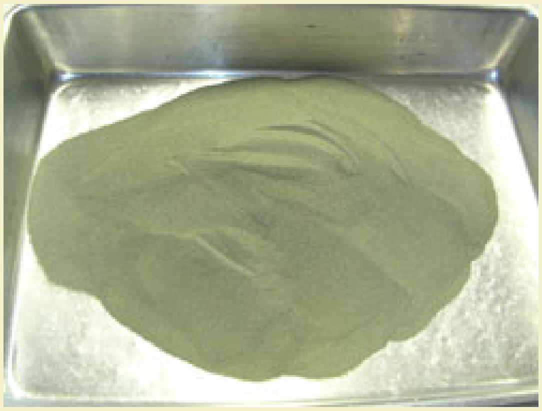

Figure 3: The coated magnesium after

Coating with Dichromate

As seems to be a general rule in pyrotechnics, the chemical that does the best job is also the most hazardous to your health. Potassium dichromate (also called bichromate) is one of the more hazardous substances on your chemical shelf, but it is the only option for preparing magnesium that will be coming into contact with ammonium perchlorate. A close-up of the bright orange potassium dichromate crystals can be seen in Figure 1, which is poisonous, corrosive and carcinogenic stuff that you don't want coming in contact with any part of your body. Read the full MSDS warnings here.

Prepare the magnesium to be coated by running it through a 50 mesh screen to remove any large chunks and break up any lumps that can sometimes form while sitting in storage. The magnesium is then transferred into a metal cooking pan similar to the one shown in Figure 2, then placed in an oven set to 210 degrees F (100 degrees C) for one hour.

The amount of dichromate used to coat the magnesium is weighed out as 5% of the weight of the magnesium to be coated. For this example we are coating 1000 grams, so 50 grams of dichromate would be weighed out and dissolved into 10 ounces of hot water (300 cc). The volume of water is adjusted to maintain the same ratio for producing larger or smaller batches of magnesium (example: 20 ounces for a 2000g batch).

After removing the heated magnesium from the oven, quickly add the warm dichromate solution and mix it in using gloved hands. This should be done out doors while wearing a respirator. It is important to avoid skin contact with the dichromate solution, as it will burn your skin and can even cause cancer with repeated exposure over time.

Once the solution has been completely worked into the powder so that there are no more dry spots, the damp magnesium is spread out on a sheet of paper to dry. A drying box can be used to accelerate this process, but care must be taken not to let the powder fully dry before screening it the first time.

While the powder is still slightly damp, run it through a 30 mesh screen in order to break up the clumps. If the powder is allowed to fully dry, the clumps will be more difficult to return to a powdered state. This is one of the tricks to making this process easier. After screening one time, allow the powder to fully dry and then screen one final time. It is especially important to wear the respirator and screening.

work outside during this screening process, as the poisonous dichromate dust will become airborne.

Once dry, you should have a greenish yellow pile of free-flowing magnesium as seen in Figure 3. The procedure is really quite simple once you can get past your phobia of the scary orange stuff!

Despite the extra safety precautions that must be taken when dealing with hexavalent chromium, some commercial manufacturers still find it faster and more economical to treat their magnesium with dichromium rather than deal with the more time consuming methods of coating with linseed oil. The hazardous leftovers and waste water from dichromium operations can be treated with ferric sulfate in order to convert the hexavalent chromium to a less toxic trivalent state prior to disposal.

For the hobbyist, the extra labor and extended drying time when coating magnesium with linseed oil may be worth the effort if it means not having to worry about avoiding contact with dichromium. In part II of this article we will look at the procedure for preparing linseed oil and coating magnesium with it.

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Technique...

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Hand Rolling Match Pipe

by Kyle Kepley

Introduction:
Making your own quickmatch pipes may seem like just another tedious process for the obsessive pyro who is already making homemade charcoal, homemade BP and maybe even homemade chemicals. With high quality commercial quickmatch available from places like Precocious Pyrotechnics for as little as 11 cents a foot, why bother?

Well, not everyone has the option of being able to buy commercial quickmatch, due to shipping limitations, storage problems and availability. But all that aside, making your own quickmatch and shell leaders really isn't that hard and takes less time then you may think. Using the process shown here, you can manufacture the pipe at roughly three feet a minute, which includes the time spent cutting the paper (assuming you have an efficient means for cutting the strips). Using the black match procedure featured this month will allow you to make about 300 feet of black match in an hour. It is then possible for you to make piped match at a rate of about 75 ft per hour when accounting for the time spent transferring powder in and out of a ball mill, rolling the pipe and spinning the match.

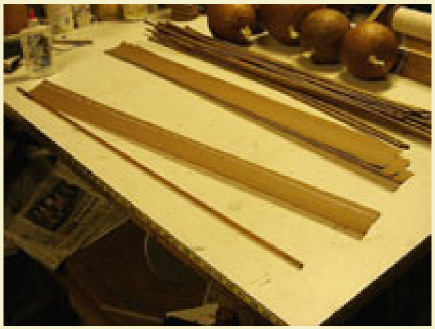
Figure 1: Strips ready for rolling.

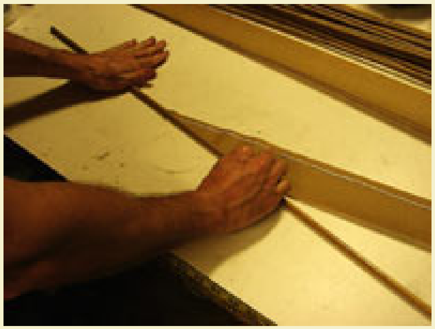
Figure 2: Rolling at an angle creates spiral wound pipes.

Rolling the Pipe:
The pipes are best rolled from a virgin type kraft paper in the 30 to 40 lb weight range. Using recycled kraft can create tearing problems when the match is folded up to make shell leaders. The width of the strips will be determined by the diameter pipe you are making. A 1/4" I.D. pipe should use a 3" wide strip, while a 3/8" I.D. pipe needs at least a 4" wide strip. The strips are easiest to cut from 36" rolls of paper fed over a slotted cutting board and cut with a utility knife.

The strips are rolled on a waxed dowel rod so that it is easy to remove the paper. The type of wax used should be the candle making variety, as bees wax is to tacky. A block of wax can be purchased in an arts and craft store, then simply rubbed across the dowel on all sides until it is coated in wax.

The trick to rolling such long strips of paper is to spiral wind them at an angle. The strip is placed at an angle to the rolling stick as shown in Figure 1, and a thin bead of white glue is run down the back edge. The paper is fed under the stick starting at the corner, then one hand is used to roll the stick while the other hand continues to feed the paper under the leading edge of the stick as shown in Figure 2. Once you get the feel for it, the rolling process will go quite fast.

Once the paper is fully rolled up, it is rolled a few times against the table to flatten down the edges and then removed from the stick as quickly as possible. Over rolling the tube and leaving it on the dowel too long will make it difficult to remove, as the glue works its way through the paper into the inner layers in contact with the dowel rod after a short period of time. Speed is the key to removing the tube. If it does stick, alternate pulling from the top and pushing from the bottom to loosen it up. Otherwise you will either rip the pipe from pulling too much or crumple it from pushing to hard. As the pipe softens from the glue, your chances of saving a stuck pipe diminishes to the point that you eventually have to tear it off and throw it away.

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Hand Rolling Match Pipe...

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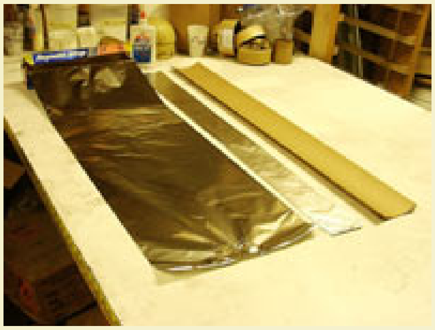
Figure 3: Preparing strips of aluminum foil.

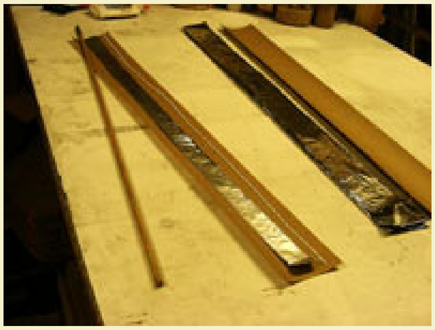
Figure 4: Placement of the foil strip.

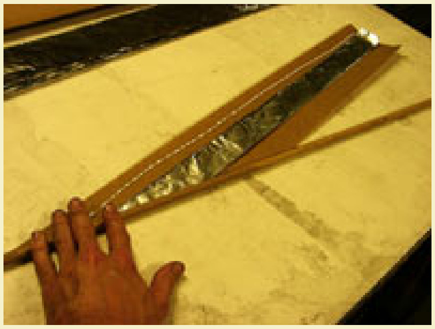
Figure 5: Rolling Tard Match.

Making Fire Retardant Pipe:
One advantage to rolling your own match pipe is the ability to make specialized varieties of pipe. The type of pipe shown here is a fire retardant variety I developed for use in set pieces to prevent accidental ignition while sitting in the field during a show.

Because set pieces are often subjected to showers of sparks from mortar debris, shell fallout and other set pieces, they sometimes accidentally ignite when hot sparks burn through the thin quickmatch paper. Some set pieces also risk igniting portions of themselves out of sequence, such as when the horizontal drivers of a girandola burn through the match ring leading to the vertical drivers, sending it skyward before it is ready and possibly throwing off the timing of other effects.

The pipe shown here, which I call Tard Match(tm), will greatly reduce the chances of accidental ignition. In tests with a blowtorch, this pipe provided flame resistance slightly less than pipe that is externally wrapped in foil tape, but much greater than standard match pipe. Note that it is much easier and cleaner to make and use this pipe rather than covering all your exposed pipe with expensive foil tape, and the heat from a blowtorch is much greater than a typical spark will create.

I make this type of pipe with a 3/8" I.D., which allows plenty of room for multiple strands of black match and other strands inserted at junctions. The strips should be 4" wide and 36" long.

The foil strips are prepared by rolling out a length of foil equal to the length of the paper strips, as shown in Figure 3. A 12" wide roll of good quality foil such as Reynolds Wrap should be used as opposed to the thinner store brand types. The foil is folded along its length twice so as to form four sections that are 3" wide, which are then cut apart with scissors.

Each 3" wide strip of foil is now folded in half and centered on the paper strip that is to be rolled, as seen in Figure 4. A bead of white glue is applied along the top edge above the foil and rolled as previously described. It is important that the foil is centered on the paper, as this keeps the foil from being exposed on both the inside and outside of the match. While the foil could be aligned flush with the bottom of the strip and rolled up, this would result in a pipe with exposed foil on the inside. Exposed foil on the inside of the pipe presents problems when cutting, adding junctions and inserting the match, as any cuts will pinch the foil closed and block the passage of the match.

Figure 6 shows the finished match pipe, which has a double layer of foil sandwiched between the inner and outer paper layers of the pipe. With the protection completely hidden, your fellow pyros will wonder how you get your

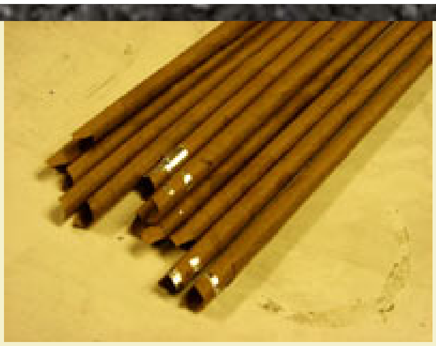

Figure 6: Finished Tard Match pipes.

set pieces to survive down wind fire storms without accidental ignition!

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Color to Report Cake

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Introduction:
Cake items are deceptively laborious items to create, which could explain why so little is written about their construction. On the plus side, cakes require very little composition to produce while also providing a long effect duration compared with chemical hungry items such as aerial shells. They are ideal for the beginner with a low budget or limited shoot sites, since 100g batches of color comp can make several cakes and shooting them does not attract much attention in areas where class C items are already legal.

Cakes can range from simple arrays of single shot star guns to complex assortments containing timed volleys of whistles, shells, tourbillions and essentially anything that can be shot out of a tube. The limited space constraints and timing issues provide many challenges for the pyrotechnician to master, and attempting to make this type of device brings a new level of appreciation for the extreme level of refinement the Chinese have achieved in this area.

Hobbyists who specialize in this particular spectrum of pyro are often referred to as "micro guys," since they must create very tiny effects to fit in the small tubes cakes require. A few micro guys even go so far as decorating their cakes with authentic looking wrappers, complete with warning labels, directions and of course a Chinese sounding name!

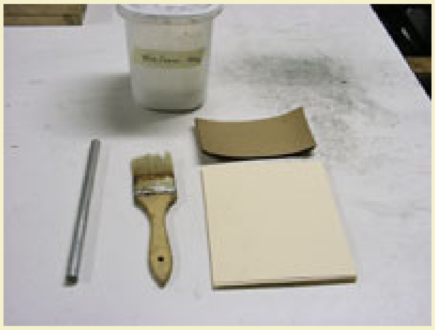

Figure 1: Materials for hand rolling tubes.

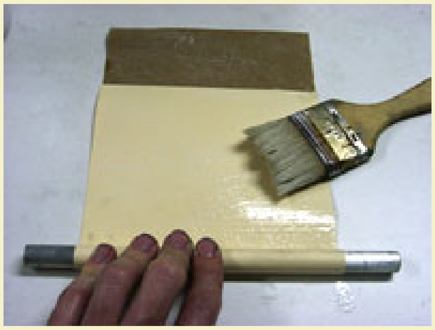

Figure 2: Applying diluted white glue to paper before rolling.

The construction method shown here is used in many common cake effects, so it is a good starting point for learning about basic cake construction. Many cake loads consist of a thin walled tube plugged at one end with a recessed clay plug, with a rising effect composition filling the recess and providing the timing. The tube can contain a report, breaks of colored stars, spinning effects, flying fish fuse or whistles to name a few. For this project the effect will be a colored rising comet to a report.

Making the Shot Tubes:
There are two tubes you will need to make this type of cake: the mortar and the shot. If you can buy both tubes in the size you need, then you can save yourself some work. But usually you have one tube on hand and must roll the other. I prefer to roll the shot to match whatever I have laying around for mortars, since the shot tube is smaller. I happen to have a very large supply of 6" long x 5/8" I.D. tubes that were given to me by a very generous passfire member, so I will use that as the mortar and design around it. The size is not critical, so feel free to adjust things to match what you have. If you make the shot exactly as shown here, you can shoot it out of tubes ranging from 5/8" to 3/4" I.D. with a length between 4" and 6". Shorter tubes will just require slightly more lift.

The shot tubes are 1-1/2" long with a 1/2" I.D. and an O.D. just under 5/8". I make these by first rolling 6" long tubes and then cutting them into four segments as seen in Figure 3. Each tube is rolled from a 6" square sheet of file folder paper, which makes very strong tubes that are also easy to roll. The first turn is wrapped around the former, as seen in Figure 2, then a mixture of white glue diluted 50% with water is brushed onto the remainder of the sheet and also on the small strip of 30 lb kraft that will make up the last few turns. The purpose of the thin kraft sheet is to keep the stiffer file folder paper from

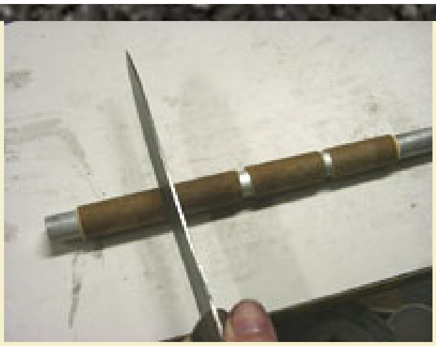
Figure 3: Cutting 6" tubes into 1-1/2" segments.

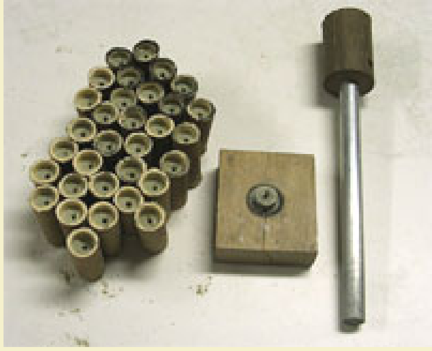
Figure 4: Clay plugs rammed and drilled.

unrolling once it is rolled.

Do not be tempted to use dry-rolled tubes for cake shots, as the lift pressure will blow the core through and telescope the case like a Chinese yo-yo! The layers of paper must be bound to each other to prevent this problem.

Cutting the tubes into segments while they are still on the former is the best way to get a nice clean edge, although it does tend to score up your rolling rod. Pressing down with a good sharp knife while moving it forward to spin the rod around should separate the tubes after about two complete turns.

You will need 24 shots to make this cake, but it is good to roll a few extra for tests. A food dehydrator can be used to accelerate the drying of these tubes, or even a wooden box heated with a 100W light bulb will do the trick.

Once the tubes are dry, you will need to ram a thin clay plug at the end of each one such that it is recessed from the end by 1/4". A block of wood with a segment of aluminum or wood dowel sticking out by 1/4" is required for making the plug, as seen in Figure 4. The plug only needs to be about 1/8" thick, and it does'nt need to be rammed as hard as a rocket or gerb nozzle would be.

Next you will need to drill a 1/8" passfire hole through all the plugs. You can fabricate your ramming base with a 1/8" pin and use a hollow drift if you want to form the hole and the plug in one operation. Make the pin at least 1/2" long if you go this route.

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Making Black Powder

Introduction:
Perhaps one of the most popular topics on pyro newsgroups and forums is the manufacture of home made black powder. Given the rising costs of commercial powder, not to mention the increasingly intrusive Federal regulations dictating the purchase and transportation of commercial BP, it is not surprising that more and more hobbyists are making their own. With good quality BP being the lifeblood of fireworks itself, making BP is often the first hurdle the new hobbyist will face.

This article marks the last in a series explaining everything you need to make your own black powder that meets or exceeds the quality of commercial powder. The following articles from past issues describe the tools and techniques you will need to use in this article:

Making your own Charcoal
Ball Mill Design
Ball Mill Construction
Ball Milling Jars
Ball Milling Media
Powder Die
Hydraulic Press
Corning Machine

The Ingredients:
Going under the names gunpowder, black powder or meal powder, this formula is old as dirt and is the foundation of all pyrotechnics. Meal powder is the name given to the finely ground powder that has not yet been processed into black powder grains. Black powder refers to the granulated powder in all its various grain sizes. Making meal powder is the first step in making black powder, and meal by itself is used extensively in many other processes as well. Most often the meal will be combined with 5% dextrin and used for priming, making black match, coating onto inert fillers for shell burst charges and wet-screening into rough powder. When making black powder, however, no dextrin is added to the meal.

Potassium Nitrate	**75%**
Charcoal	**15%**
Sulfur	**10%**
Dextrin (optional)	**5%**

In most cases you will want your meal to burn as fast as possible. This is because the major uses of your finished black powder include lifting shells, breaking shells, priming stars and making black match. Thus the stronger your powder is, the more effective it will be.

There are two major factors that will determine the strength (burn rate) of your meal powder: the integration and fine granules of the three components and the type of charcoal used. Following the guidelines given in the ball milling articles mentioned above will result in very fine and intimately mixed powder. As for the charcoal, the fastest burning powders are typically made from willow, paulownia, grape vine or spruce. The commercially available charcoals sold as "air float" typically include an unknown mixture of many kinds of wood and, while it can be used to make passable BP, it will not result in an optimal product. When burn rate is critical to performance, such as cross match on insert shells or outer primes on color changing stars, BP made from commercial air float charcoal is not recommended. Using the spruce wood commonly available as construction grade lumber (not to be confused with pine) to make your own charcoal will result in a very fast powder that meets even the most demanding applications.

The purity of the potassium nitrate is actually not as critical as some people make it out to be. Fertilizer grade nitrate, such as the type sold under the name K-Power, will work just fine for making high quality meal or BP. K-power brand typically sells for $15 per 50 lbs, making it a very economical option. However, this nitrate comes in a granular "prilled" form and must be ball milled by itself to reduce it to a fine powder before use in making BP. While the prills will reduce the caking problems associated with nitrate, it will still clump in the bag and force you to break the lumps apart before mixing.

Bulk nitrate sold in 50lb bags ($20 to $25) from commercial suppliers such as Service Chemical or Hummel contain a finer ground powder with an optional anti-caking agent added. The caking agent does not effect performance of the finished BP, does not cost extra and will eliminate the hassles of grinding the unavoidable nitrate bricks that will form due to the hydroscopic nature of potassium nitrate.

The finer the nitrate has been ground, the harder the clumps that form over time will be to break apart. Some commercial operations use agricultural grinders to pre-process clumped nitrate before milling. For the average hobbyist, placing the chunks in a large stainless steel bowl (see Figure 1) and crushing them with the end of a heavy steel rod will do the job. The chunks only need to be broken down into smaller pieces that the mill will be able to grind up. It is a good idea to only de-clump and mill your nitrate right before use rather than mill a lot at once and store it for later use. This is because the milled nitrate will only remain fluid for a short time after milling before clumping up again.

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Making Black Powder...

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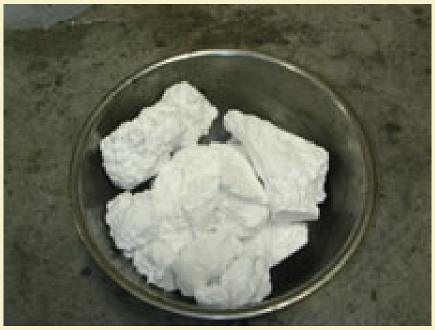

Figure 1: Clumped potassium nitrate pounded in a stainless steel bowl.

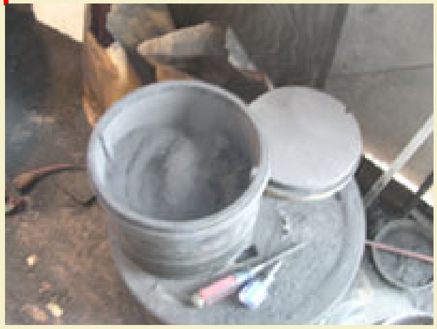

Figure 2: Loading a ball mill jar.

Procedure:

There is no need to screen the materials being used to make BP, since the mill will grind and mix them quite well. Gravel sized nitrate chunks and quarter inch sized charcoal chunks can be combined and milled in such a crude state and still produce a fine powder in the end. The ingredients can simply be weighed out, thrown into a container with a lid, shaken around to mix them together roughly and then dumped into the mill jar for milling.

The procedure I prefer to use for making meal powder involves milling the charcoal and sulfur together in a 3:2 ratio first, then milling the nitrate with this C/S mixture in a 6:2 ratio to get the final product. The C/S mixture is milled for two hours, and if fertilizer nitrate is being used then that is milled by itself for 2 hours as well. The two are brought together and milled for only one hour, thus reducing the amount of time spent milling the live BP mixture.

The amount of ingredients to charge your mill with will depend not only on the size of your mill jar, but also on the density of your charcoal. This is because mill jars are charged by volume and not by weight, and charcoal can vary considerably in the volume a given amount consumes. For example, a light and fluffy charcoal made from spruce will consume about 20% more space than the same amount of commercial air float charcoal.

The calculator below attempts to help you find the right amount of materials to charge your mill with. Based on my own experience, these amounts should result in a charge that is 25% of your mill jar by volume. Using the commercial airfloat and home-made spruce as the two extremes, entering your jar I.D. and length will estimate the charge amounts for you. The numbers in the tables should change as you type in the boxes, otherwise your browser is incompatible with this script and you will need to download a newer version.

Jar I.D. 6 in.

Jar Length 8 in.

Spruce Charcoal

Step 1: Mill 1000g KNO3

Step 2: Mill 300g C + 200g S

Step 3: Mill 600g KNO3 + 200g C/S from Step 2

Optional: Add 40g dextrin to Step 3

Commercial Air Float Charcoal

Step 1: Mill 1000g KNO3

Step 2: Mill 360g C + 240g S

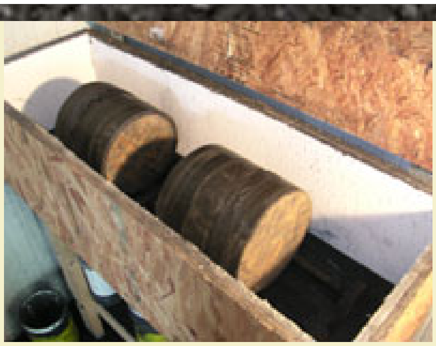

Figure 3: Milling with dual 8" HDPE jars.

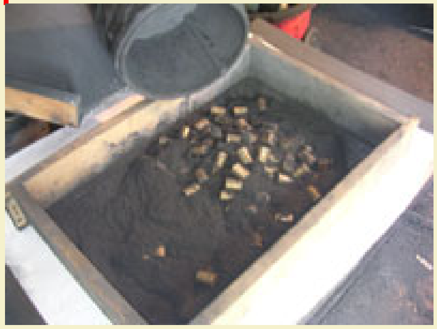

Figure 4: Screening media from meal powder.

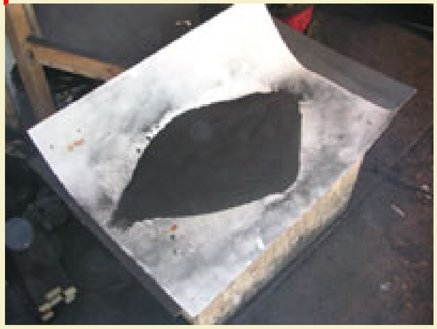

Figure 5: Using poster board for easy transfer of material after screening.

Step 3: Mill 720g KNO_3 + 240g C/S from Step 2

Optional: Add 48g dextrin to Step 3

NOTE: Mill steps 1 and 2 for two hours, then step 3 for only 1 hour.

The amounts given in the table above should fill an empty mill jar 1/4 full. If it doesn't, then you will have to adjust the amounts so that it does. The jar is first charged half full of media, then the components to be milled are added as shown in Figure 2.

Note that dextrin is milled with the mix when it is required. This does not cause any clumping in the mill jar and is a lot easier than screening in the dextrin after milling.

Using a double jar mill with 6" I.D. x 8" long jars, you can mill two batches of nitrate at once for two milling sessions, giving you 4000g of nitrate. Then mill two batches of the C/S mix at once. You will then have enough pre-milled ingredients to make four jars worth of finished meal.

When milling is complete, the media is typically separated from the powder through the use of a coarse screen box as seen in Figure 4. The screen is rocked back and forth as the media pushes the powder out the bottom and onto a piece of poster board or sheet of kraft paper. The paper makes it easy to transport the finished powder into a storage container, as seen in Figure 5.

Since the media can be quite heavy, screens used for separating the media tend to wear out fast or bulge over time due to the weight. One method to increase the life of your strainer screen is to use a stronger, coarse screen overlaid with a finer non-sparking screen made of stainless, brass or aluminum. The large screen supports the weight, while the finer screen breaks up clumps and allows the media to slide around easier.

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Making Black Powder...

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Pressing:

The next step in manufacturing black powder is to compress the meal powder into hard pucks that look like hockey pucks. These pucks will later be broken into pieces in a process known as "corning," which gives the final gravel like product. Pressing is an important step in the process, as this is what controls the density and thus the burn rate of the finished powder.

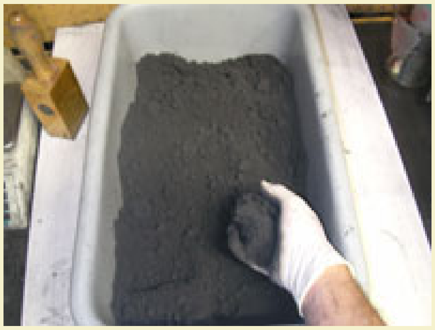


Figure 6: Meal dampened with 10% water.

Density is defined as the amount of mass contained in a given volume. The ideal density to press your powder is generally accepted to be 1.7 grams per cubic centimeter. I have never made specific efforts to achieve this exact density, as I've never had any problems getting my powder to do what it is supposed to do. If you are curious about the density of your BP, measure the height of your pressed powder cylinder, weigh the dry results of the powder you make from it and enter the values into the calculator below. Note that you can enter any three values and it will calculate the fourth value, which can be useful for finding the amount of powder and depth of pressing for obtaining a specific density.

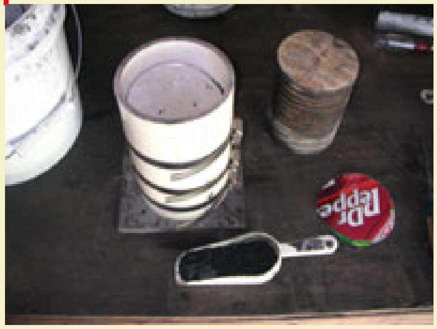
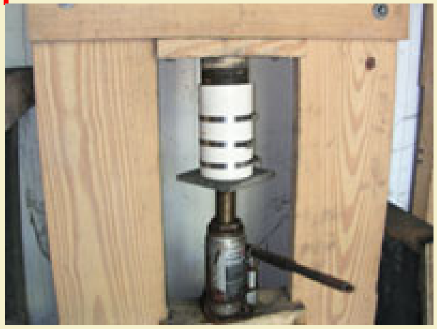


Figure 7: Loading the powder die.

Pressed Diameter:	☐	cm	○ solve for this
Pressed Height:	☐	cm	○ solve for this
Dry Powder Weight:	☐	g	○ solve for this
Density:	☐	g/cubic cm	○ solve for this

Calculate

Since my powder has always performed well for the purposes of lifting and breaking shells, I have never fretted over density. I have measured the density out of curiosity, however, and found it to be pretty close to the 1.7 mark. Thus following the procedure given here will give you good powder without worrying about density. If you are a density control freak, you can use the calculator above to figure out the required grain height for a given weight of powder in order to obtain a density of 1.7, then mark your piston with a stop line showing where to press to.



Start by dampening your meal with 10% water that has a small amount of alcohol added to it (5%) to help break the surface tension and make mixing easier. Some will argue that 10% is too much water, but it is my experience that using a higher amount of water actually results in drier pucks that are pressed harder. It is my theory that the extra water helps lubricate the powder, allowing it to compress further. I've tried 8% and 6% and the resulting pressings were not as hard and crisp as when using 10%. Since the process described here requires that the pucks be corned immediately after pressing,

Figure 8: Compressing 8 pucks in a 12 ton hydraulic press.

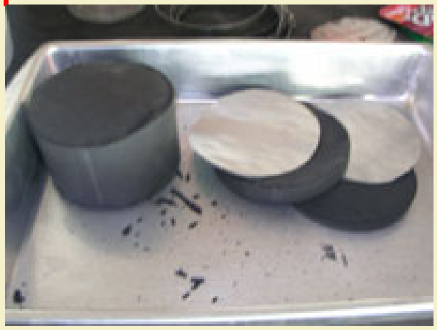


Figure 9: Splitting the pucks apart.

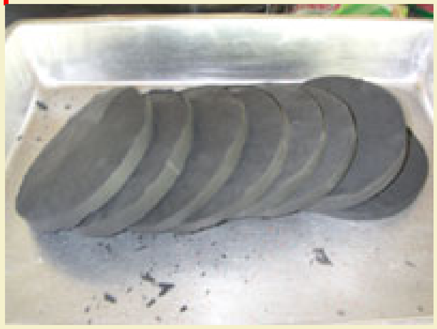


Figure 10: The finished pucks.

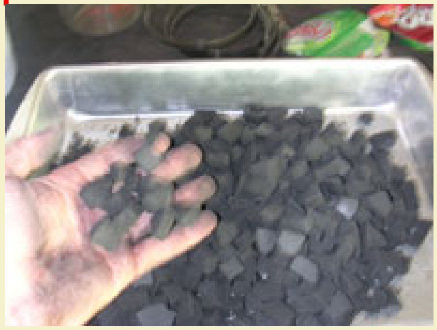


Figure 11: Rough breaking the pucks by hand to feed the corning machine.

it is important to have crisp pucks with most of the water pressed out of them. The 10% moisture will actually result in dryer pucks than if you used 8%, believe it or not.

A good amount of powder to work with here is 3200g of meal. This will give you three pressings using the powder die described here, plus a forth pressing using the leftover corning dust from the first three pressings.

Rather than press single pucks one at a time, it is more efficient to press many at once. In a theoretical, friction-free world the force required to press one small disk would be equal to the force required to press many. However, friction is a very real part of the real world and the amount of force required to overcome the friction between the powder and the sides of the cylinder wall increases substantially with the length of the pressing. A 12 ton press will be required to handle pressing 8 disks with a total compressed height of about 3.5 inches.

After the powder has been dampened, place your powder die on a metal block that will support it on the press (see Figure 7) and begin loading increments of powder followed by an aluminum separation disk. The powder increments should be about one cup of powder, which will compress to give you pucks about 3/8" thick. The size of the powder increment is not that critical, as it will only control the thickness of the puck and not density. You don't want your pucks to be much thicker than 3/8" or it becomes difficult for the corning machine to break them into pieces. Thinner pucks should not cause any problems, but 1/4" to 3/8" seems to be the best range.

The thin aluminum disks, cut from soda cans, are used as separators so you can get the pucks apart when you are done pressing. They should fit into the pressing sleeve with very little gaps around the edges, otherwise the powder will adhere around the edges and "glue" the pucks togehter, making them difficult to separate.

After about four increments have been loaded, insert the rammer and compress the powder by hand. Then load the other four increments and finish with an aluminum disk on top. Compress by hand one last time and then load the die into your press as seen in Figure 8.

In addition to using a strong press, you will also need to allow plenty of dwell time when pressing. Begin by cranking the lever as hard as it will go, then return 10 minutes later and crank it again. You will find that considerably more compression can be made after it has been allowed to settle for a while. After 15 minutes you will begin to see water seeping out around the bottom of the sleeve. While this water does carry out some dissolved nitrate, it is not enough to effect performance and it is important to try and squeeze out as much water as you can before unloading the press. I allow a total dwell time of about 30 minutes, while re-cranking the jack about every 10 minutes.

Use a rag to soak up any water around the base plate of the die, then unload it from the press. The bottom and top of the powder grain will be damp, so it helps to quickly wipe this with a rag as well to keep the water from soaking back into the powder grain.

Figure 9 shows the grain removed from the sleeve with a couple of pucks seperated from it. Sometimes the pucks can be hard to seperate at first. Warming the pressed grain with your hands can cause it to expand slightly and help the pucks to crack apart. The pucks should be hard and brittle, with sharp edges when broken apart. Softer pucks will corn faster, but result in a higher percentage of unwanted corning dust. Softer pucks are also an indicator of a lower density pressing.

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Making Black Powder...

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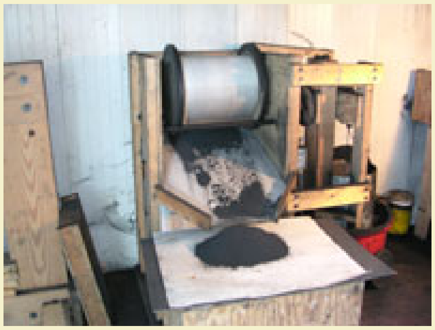

Figure 12: Corning machine in action.

Corning:

When using the Passfire corning machine described here, breaking the pucks up into large pieces will help lower the corning time, as seen in Figure 11. These pieces are simply loaded into the screen port of the machine, which is then closed up and turned on. The machine can be seen operating in Figure 12, with a large pile of corned powder building up in front of it. The machine shown here also has a stamp mill for grinding charcoal built onto the side of it, which uses a power take-off shaft from the corning machine to power it (future tool-tip article).

It will usually take the corning machine 30 minutes to grind up the two pound batch of pucks shown in Figure 11. Before turning on the machine, prepare your next 8-puck pressing and let your press be dwelling on it while the corning machine grinds the current batch.

Screening:

The last step in making your black powder is to separate the different grain sizes you want using screen boxes. The screen sizes for the range of commercial powder sizes are as follows:

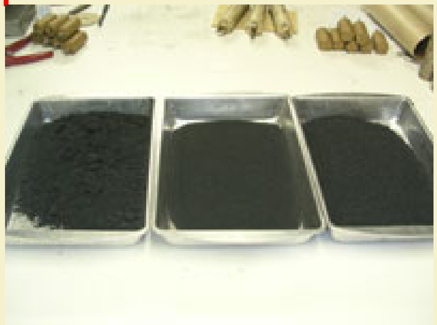

Figure 13: Corning dust, 2Fg and 3FA.

U.S. Blasting Powder Grain Size

GRADE	MESH RANGE
FA	3 - 5
2FA	4 - 12
3FA	10 - 16
4FA	12 - 20
5FA	20 - 50
6FA	30 - 50
7FA	40 - 100
Meal D	+ 50
Fine Meal	+ 100
X-Fine Meal	+140

Black Powder Grain Sizes

GRADE	MESH RANGE
Cannon	6 - 12
Saluting	10 - 20
Fg	12 - 16
2Fg	16 - 30
3Fg	20 - 50
4Fg	40 - 100

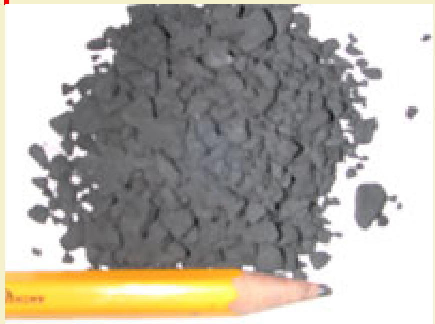

Figure 14: Closeup of 3FA.

While you could go through all the trouble of screening out each of these, I find that you really only need two size ranges for pyro use. A large grain in the 2FA to 3FA range is used for lifting and breaking shells, while a smaller size in the 4FA to 5FA range is used for lifting cake items, breaking small insert shells and dip-priming operations. This way you only need three screens to do the job and less containers to store the results.

Since the powder has already passed through a screen on the corning machine, you only need two additional screens to finish the job. I use a 10 mesh screen on the corning machine, which determines the largest particle size that will be present. The powder that is collected from under the corning machine is then passed through a 16 mesh screen. The grains that sit on the 16 mesh screen are shown in Figure 14. This powder would be the equivalent of 3FA and will be used for lift and break charges. While 2FA is traditionally prescribed for this purpose, 3FA works just the same. If you wanted 2FA, you would fit the corning machine with a 4 mesh screen and then use a 12 mesh screen for the first screening. However, the coarser the screen on the corning machine is, the less fines you will get and thus the less powder you will have for cake items and insert shells. This may be more desirable depending on what type of powder you consume more of.

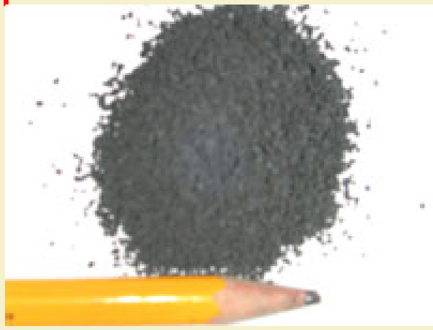
Figure 15: Closeup of 2Fg.

For the second screening I use a 30 mesh screen. Everything that sits on this screen is used for lifting cake items and breaking pupadelle type insert shells. This powder, shown in Figure 15, is the equivalent of 2Fg, which is a grain powder designation that covers a range between 4FA and 5FA in the blasting powder designation.

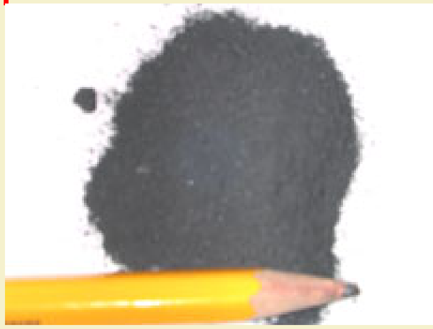
Figure 16: Closeup of corning dust.

The resulting "corning dust" is everything that passes the 30 mesh screen, as seen in Figure 16. This is a little more gritty than Meal D, and makes an excellent dusting powder for priming applications. It can also be used as the powder train when making Chinese paper fuses to give a very fast burning fuse for cross match or crossette passfires. Or you may opt to just save it for the next pressing operation and produce more grain powder from it. For every three batches of pucks that you process as described here, you will have enough corning dust left over to press a fourth batch.

Ideally the amount of corning dust generated is minimized, even though it has a number of uses. There are a number of variables that will determine the yield from the corning machine, including the dampness of the grains when they were ground, the hardness of the grains, the rigidity of the corning drum, the type of drop media used and how effectively the media strikes the powder grains. The yield for the batch used in this article was as follows:

3 Batches Made From Meal		
Corning Dust	886 g	28%
2Fg	844 g	26%
3FA	1447 g	46%

1 Batch Made From Corning Dust		
Corning Dust	310 g	35%
2Fg	224 g	25%
3FA	350 g	40%

Total Production		
Corning Dust	310 g	10%
2Fg	1068 g	34%

3FA	1797 g	56%

The data suggests that re-pressing corning dust results in slightly less yield than pressing unprocessed meal. This indicates that the aggregate mixture that makes up the corning dust results in a more crumbly puck, even though you do not notice them being any different when snapping them apart by hand.

The final table shows how much yield you will get from the entire process, which will take about three or four hours of intermittent work to produce. The grains will be nearly dry after screening and ready for use after only one day of sitting on a sheet of newspaper. Using a drybox will have your powder ready to use in only about 8 hours. The finished grains should be hard and sharp, and you should not be able to crumble them under your fingers.

Some BP makers add an extra step of tumbling their dried grains with a small amount of graphite or powdered aluminum to facilitate the ability to flow well when poured from a container. This is really not necessary since the raw grains will flow well enough for pyro use, but the graphite will give that shiny finish if you desire powder that looks like it came right out of a Goex can!

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Technique... **Page 1**

Making Chinese Paper Fuse

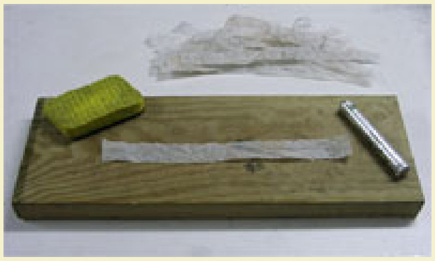

Figure 1: Rolling board, wet sponge, powder applicator and strip of tissue.

Introduction:

It is likely that the first type of fuse you ever came across as a kid was that powder leakin', fire-skippin' paper wick sticking out of a firecracker. While this type of fuse is hardly ever used in class B fireworks due to its inconsistent burn rate and poor fire transfer characteristics, it does have the advantage of being quite flexible and small in diameter. It is ideal for use in small devices such as firecrackers, jumping jacks, bottle rockets and spinners like buzz-bombs, hummers and ground bloom flowers where fire needs to be passed through a very small diameter hole.

Materials:

The key to making this type of fuse is the type of tissue paper that must be used. While it isn't a true hand made gampi paper, it has similar characteristics in that it has good wet strength and does not tear easily. The paper is similar to that used to make coffee filters, although it is a thinner grade. A good place to find this kind of paper is hobby shops that sell balsa wood airplane models. The paper is sold in 2x3 sheets and is used to skin the finished planes. The paper is applied over the airplane frames while it is dry, then sprayed with water. Upon drying, the paper shrinks and forms a tight skin over the frame.

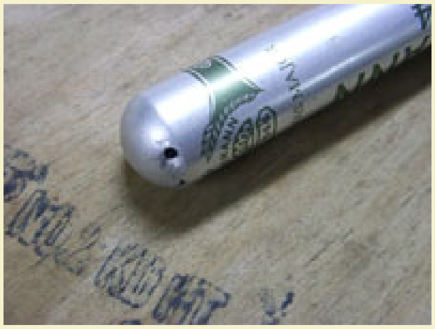

Figure 2: A 5/64" hole drilled at the bottom of a cigar case.

This shrinking characteristic also helps when making fuses, since it reduces the tendency for the dried fuse to unravel.

Figure 1 shows everything you will need to roll your own Chinese fuse. A wooden rolling board, a wet sponge and a special powder applicator made from a capped tube. Aluminum cigar cases make ideal powder applicators, since they have a rounded bottom and a screw on cap for loading in the fuse powder. The plastic test tubes sometimes used to serve shots in a bar also work good if you have a cork that will fit the end. Simply drill a small hole at the bottom as seen in Figure 2 and fill the tube half full of powder.

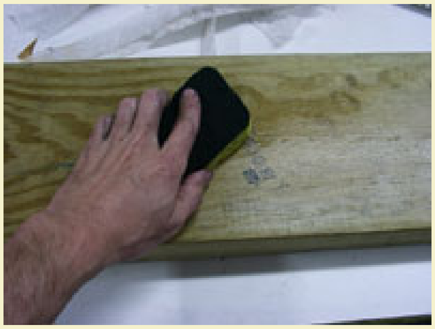

Figure 3: Pre-wetting the rolling board with a damp sponge.

Procedure:

Begin buy cutting strips of the gampi tissue that are about 3/4" to 1" wide. Make sure you cut the paper so that the grain runs the length of the strips. The length of the strips are not critical, but it is easiest to work with lengths that are about a foot long.

These fuses are rolled in a wet state, so it is necessary to roll them on an untreated wood surface that will absorb water to prevent pooling on the surface. Use a damp sponge to wet the surface of your rolling board before laying down a strip of tissue, as seen in Figure 3. Lay a strip onto the damp wood and sponge over it to make sure there are no dry spots.

Next take your powder applicator and tap a powder train down the middle of the strip for the full length, as seen in Figure 4. Tapping the tube against the board as you move it along should cause the powder knock out into a straight line. Ball milled black powder makes the best fuse, but it can cause clogging problems coming out of the small hole. For those of you who make and corn your own black powder, your leftover corning dust will make a very fast burning fuse that may work well as cross match, and also flow easily from the applicator.

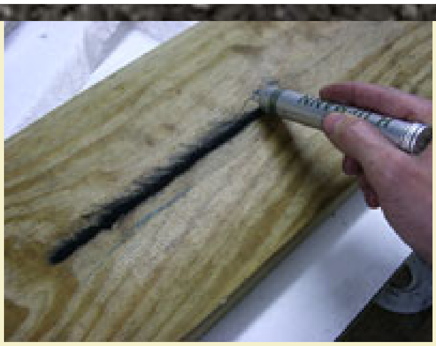
Figure 4: Tapping a powder train with the powder applicator.

Once you have laid a powder train with no gaps along the length of the paper, begin rolling it up at an angle starting at one end. Figure 5 shows the proper hand position for quickly rolling up the fuse. The left hand does the rolling, while the right hand runs along the length at the point shown in Figure 5. This can be done in one continuous motion if your strip is only about a foot long. After the fuse is completely rolled up, roll each end in opposite directions to tighten it up as seen in Figure 6. This paper has amazing wet strength and you need not worry about ripping it by twisting too hard.

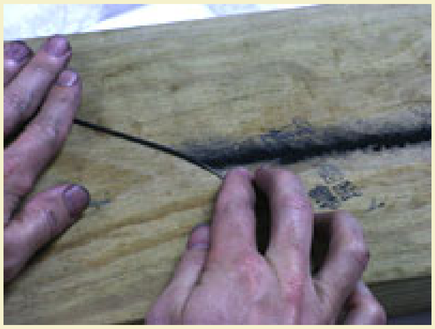
Figure 5: Hand position for rolling up the fuse.

One nice feature about this type of fuse is that it can be dried and ready to use quite rapidly. Using a heat lamp and some air circulation, you can make some fuse and have it ready to use 30 minutes later!

If your fuse burns slowly with a red glow like an inscent stick, then your powder train wasn't thick enough. Using unmilled green mix will also create slow burning fuse with lots of dross. It is the general nature of this fuse to burn with rapid skips that render it useless for any kind of timing. This is definitely not something you want to use for fusing any kind of exploding fireworks or other large effects that you would be lighting by hand. When made with corning dust, the ideal application of this fuse may be for cross matching time fuse, since it takes fire easily, burns fast and can be easily twisted into small holes without damaging the fuse.

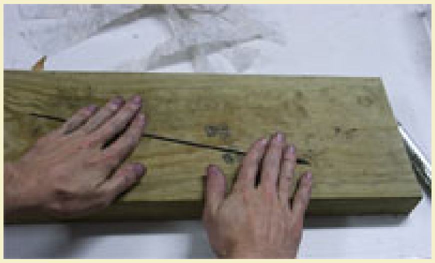
Figure 6: Twisting the finished fuse in opposite directions with both hands.

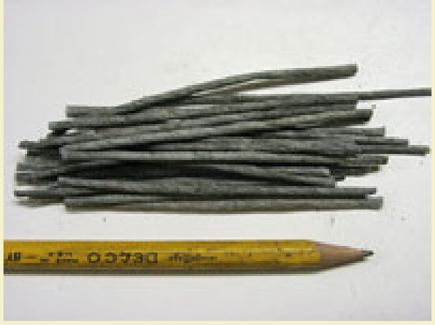
Figure 7: Finished batch of 3/32" diameter fuse.

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Tool Tip...

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Making Cross Match

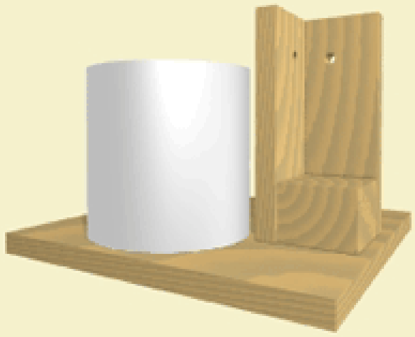

Figure 1: Sizing up the spool brackets with the slurry bucket.

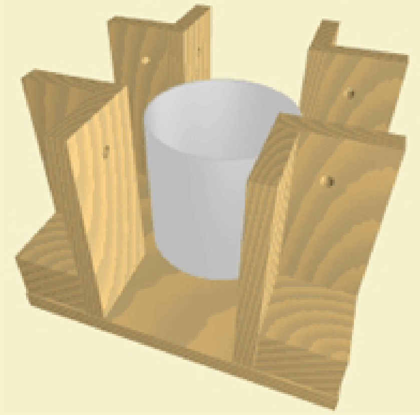

Figure 2: Bracket placement around slurry bucket.

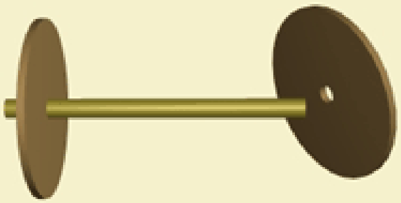

Figure 3: Making spools with brass tubing and 3" end disks.

Introduction:

Cross match is a thin diameter type of fuse used to pass fire into a piece of time fuse. The time fuse is punched through with a small diameter hole into which a short segment of cross match is inserted. Black match is most frequently used for cross match because it takes fire easier than other types of small diameter fuses such as visco or thermolite. Black match can also take fire at any point instead of just at the ends such as with visco. This side-ignite characteristic helps reduce the time required to pass fire to the main time fuse.

Because the reliability of the cross match is detrimental to insuring quick and effective ignition in shells and inserts, it is important to be able to make good cross match. Thin match that only contains a shell of powder around the outside tends to bend easily when inserted, resulting in the outer powder layer cracking off and creating a void in the powder train. This little inch of fuse can make the difference between a lot of effort working properly vs. smashing to the ground.

While the method for making black match described here can be used to make smaller diameter cross match, the method described in this article produces a more consistent diameter fuse with good powder saturation. While this technique requires more effort in fabricating the initial tooling, it is generally faster and less messy at producing match than other methods.

Making the Spool Rack:

The basic idea here is to feed four individual strands of cotton thread down into a bucket of black powder slurry, where they then merge as one strand up through a diameter regulating hole and onto a rotating frame. This way each strand is coated before merging into one strand, insuring that there is powder on the inside of the fuse as well as on the outside.

The first component you will need to make is a bucket around which four spools of string are situated. The actual dimensions will depend on whatever bucket you can find, so Figures 1 through 5 show the basic design. The bucket should be at least six inches in diameter, but no larger than 8" or you will wind up wasting a lot of slurry per fuse batch. The depth of the bucket should also be at least 6".

You will need to make four brackets that look similar to the one shown in Figure 1. The hole near the top is used to hold a rod around which the spool can spin. The bracket should be made so that the hole is about 2" above the lip of the bucket when placed next to it. The wood block at the bottom of the L shaped bracket helps hold the pieces together and gives you something to screw into when fastening the brackets to the base board. The width of each bracket face should be about 2", while the height will be determined by your bucket.

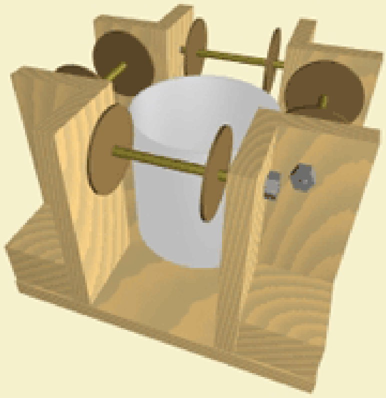

Figure 4: Spools mounted in brackets.

The brackets should be spaced around the bucket as shown in Figure 2. The spacing between each bracket pair should be equal to the diameter of your bucket. Use wood glue and screws to secure each bracket to the base board, screwing from the bottom side of the base board up into the brackets.

The four spools are made using brass tubing and chip board end disks for 3" shells. The length of the brass tubes, which can be found in the K&S Metal centers of some hardware stores, will need to be equal to the diameter of your bucket, minus about 1/4". I use 1/4" rod as the axle, so the brass tubes are 3/8" O.D. and easily slide over the axle. Drill a center hole in a set of end disks such that they make a tight fit onto the brass tube, as seen in Figure 2. The disks can be secured with hot glue if they are not a tight fit. Be sure to leave at least 1" of brass tube sticking out on both sides of the disk, which you will need for fitting into a drill chuck when loading them with string.

You will need four axle rods for the spools to spin on, which are cut 2-1/2" longer than the length of the brass tubes. This can be something like 1/4" threaded rod or 1/4" aluminum tubing with threads cut onto each end so that a nut can be threaded on. Figure 4 shows all four spools in place. The nuts at the end of each axle need only be hand tight so that the spools can be removed without the need for any tools.

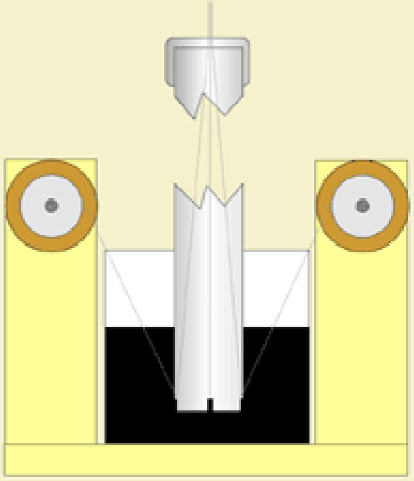

Figure 5: Thin cotton twine fed into notched bottom of PVC pipe, then up through a 1/8" hole in the capped end.

Next you will need a segment of 2" diameter of PVC that is about 2 feet long. An end cap with a 1/8" hole drilled in the center is placed on one end (not glued). The bottom end is notched with four equally spaced channels for the string to pass through. This is easily done with a thin kerf pull saw or hacksaw blade.

Figure 5 shows a cutaway of all components being used to feed string down into the slurry bucket, into the bottom of the pipe and up through the hole in the top. The pipe is stirred in actual use, which further helps coat the string with slurry. Excess slurry scraped off the string at the sizing cap falls back down the pipe into the slurry bucket, making the operation quite clean.

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Making Cross Match

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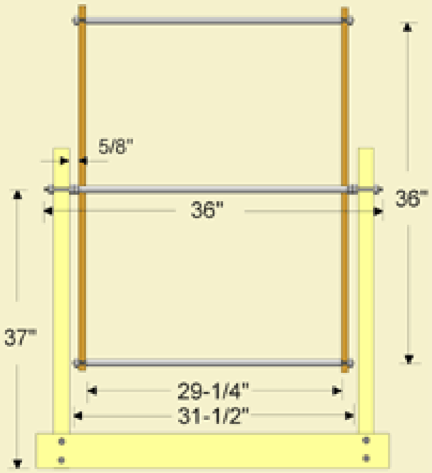

Figure 6: Match loom dimensions.

Making the Frame:

The frame used for this process is a little smaller than the ceiling mounted frame described here. Because the operator sits in front of the frame when making the match, a large frame would get in the way and be too difficult to manage.

The first step in making the frame piece is to cut the threaded rods and aluminum tubing to the following sizes:

(2) 29-1/4" long 1/2" O.D. aluminum tubing
(1) 30-3/4" long 1/2" O.D. aluminum tubing
(2) 31-1/2" long 3/8" dia threaded rod
(1) 36" long 3/8" dia threaded rod

You will also need the following components for assembly:

(4) 3/8" washers
(4) 3/8" hex nuts
(6) 3/8" lock nuts
(2) 38" long 1x2 lumber
(2) 39" long 2x4 lumber
(1) 40" long 2x4 lumber
(4) 3" long 1/4" lag screws
(4) 1/4" washers

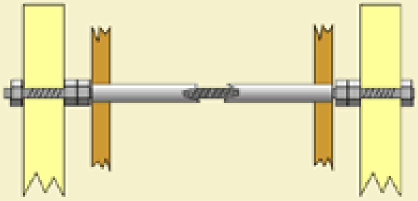

Figure 7: Details of center pivot.

A 3/8" hole is drilled on center one inch from each end of the 38" long 1x2s, which is easiest to do by clamping them together and drilling through both of them at once. A 1/2" hole is drilled on center at the midpoint of the boards, which will be the pivot point.

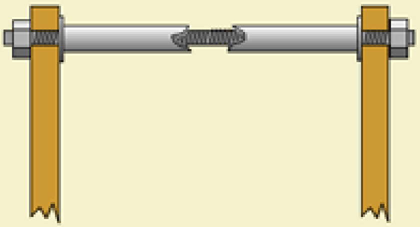

Figure 8: Details of tie-rods at each end of frame.

The frame is assembled by putting a lock nut onto one end of the two shorter pieces of threaded rod and feeding them both through the top and bottom of one frame board. A washer is now slipped onto each threaded rod, followed by the shorter 1/2" tubes, another washer, the other frame board and finally another lock nut. After the lock nuts are tightened snugly, both ends of the frame should look like Figure 8.

Before placing the second frame board onto the threaded rods as mentioned above, it is a good idea to insert the longer 1/2" tube into the center hole of one board so that it will fall into place when the two halves are put together. Otherwise the center tube will have to be slid into the side of the frame once it is assembled.

Next you will need to take the two 39" long 2x4s and drill a 3/8" dia hole on center at two inches from the end of each one. Lay the frame flat on the ground and run the remaining threaded rod through the center tube, then spin two hex nuts onto each end such that they do not actually contact the frame. There should be enough threaded rod remaining that each 2x4 post can be fitted on each side and secured with a lock nut as shown in Figure 7. The two nuts on the other side are tightened against each other and are only there as spacers.

The remaining 2x4 is used to connect the support posts at the bottom using the lag screws as shown in Figure 6. The frame may be fitted with feet to keep it upright, but I prefer to leave these off so that the frame can be stored flat up against the wall. I attach bar clamps to the bottom board to act as temporary support when I use the frame. Some hinged pieces that fold out could be used for a similar space saving purpose.

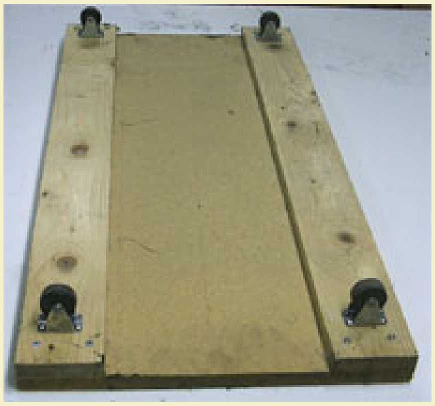

Figure 9: Fixed wheel dolly for operator to sit on.

Making the Dolly:

The last component you will need is the dolly shown in Figure 9, which is simply a 33" x 16" piece of 3/4" thick particle board with some 1x4 support planks on each edge so that it will not bend. Four fixed position casters are attached so that the dolly can only move side to side. The purpose of this platform is to allow the operator and the slurry bucket to easily move sideways as the frame is loaded with match.

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Match Making Procedure:

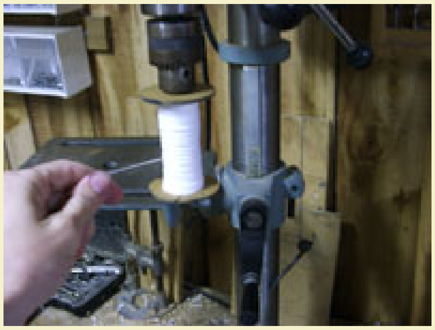

Figure 10: Loading the spools using a drill press.

The first step in preparing to make a batch of cross match is to load your spools up with string. The type of string I use is a thin mercerized cotton that is sold for crochet in arts and craft stores. You can sometimes find it in large balls, but typically it comes wound on smaller 3" dia. cardboard tubes in various colors. Each spool will require one of these smaller balls.

The thin cotton twine used to make commercial match will not work for this process because it is too weak. You should not be able to easily break the string with your hands if it is to survive the tension of being pulled under the PVC and up onto the rotating frame.

The spools are easily loaded if you have a drill press. Simply chuck up a spool as shown in Figure 10, put your ball of string in a bucket on the floor, tie off the string to the spool and run the drill at a low speed while guiding the string with your hand. Make sure you wear a glove or you will get some serious rope burn!

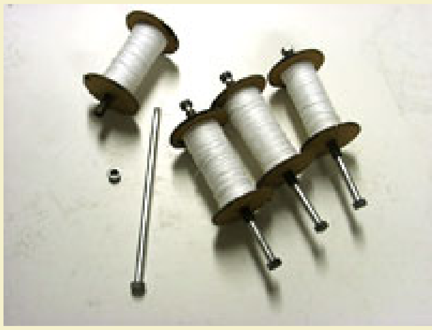

Figure 11 Loaded spools and threaded axle rods.

Figure 11 shows all the spools ready to go. A fully charged spool will do more than one frame but not quite two frames. So next time around you will have to tie on to the existing string when you recharge the spool. The knots will not cause any problems getting through the 1/8" sizing hole.

Prepare a few pounds of meal powder with 5% dextrin and add boiling water until it is a thick, muddy consistency. The bucket needs to be at least half full with the slurry so that the strings will be exposed to more of it during their passage through the tube.

Figure 12 shows the full setup ready to go. The small stool is where the operator sits during the process. A five gallon bucket with some padding on top works just as well for a seat.

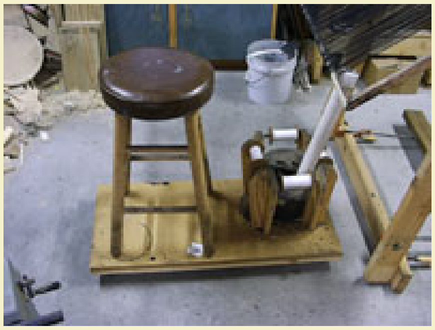

Figure 12: Match making station with slurry bucket loaded and PVC threaded.

Remove the cap from the PVC pipe and feed the four strands of string from the side spools up through the bottom and out the other end. Bring the ends together and run them through the hole in the cap, then secure the cap back onto the pipe. The group of four strings is tied off on one end of the frame and the sliding platform is moved to that side. At this point you can submerge the pipe and string into the slurry, as shown in Figure 13.

Assuming you start at the left end of the frame, use your left hand to spin the frame while stirring the slurry with the pipe in your right hand. Slowly spin the frame and guide each strand of black match so that there is about 1/2" space from the previous strand. If you start to see white spots on the strings, slow the pace down or stir the pipe more so the string is worked into the slurry longer.

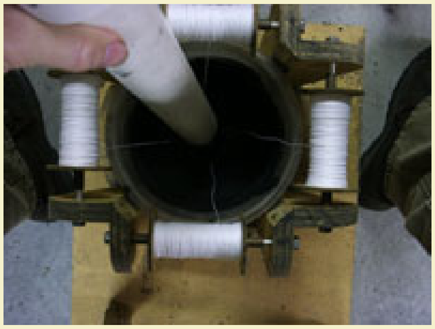

Figure 13: Stirring slury with one hand while spining the match onto the frame with other hand.

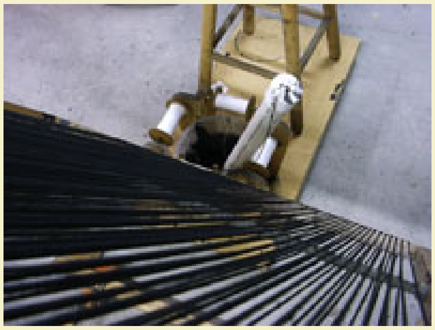

Figure 14: Fully loaded frame ready for drying.

It is usually necessary to periodically add more water to the slurry, since the string takes on slightly more water than it does powder. When the slurry starts gloping up around the edges without flowing back to the center when stirring the pipe, that's when it is time to add more water. Be careful not to add too much water, because it doesn't take much to get the consistency back to where it should be.

After about a half our of this, when your arm is ready to fall off from stirring the pipe so long, you should have a nice frame full of cross match as seen in Figure 14. The first few feet of the first strand will be uncoated, but you will simply discard that later. Allow the match to air dry for several days until fully dry, then remove by cutting along the bottom and pulling the loops off at the top.

I usually leave the top loop connected and just lift all the match off and store it in a cardboard mailing tube. Pieces of capped PVC also makes good black match storage.

If you find that the match has problems bending when being inserted through tight time fuse holes, you can make it stronger by substituting the 5% dextrin with 2.5% soluble glutinous rice starch (SGRS) in the slurry. The use of SGRS will increase the drying time substantially, but the finished match will be very stiff and less prone to cracking. It is recommended that SGRS match be removed from the frame after a few days and hung in a drying box of the type described here in order to speed up the drying time from weeks to days.

A single frame of this thin black match should last at least a year, since it can hold about 170 feet of match and you typically only use small segments of it per shell. This thin match will also work fine for piped shell leaders, but it is recommended that two strands be used instead of one. A different method for making larger quantities of thicker black match, ideally suited for shell leaders, can be found here.

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Making Cut Stars

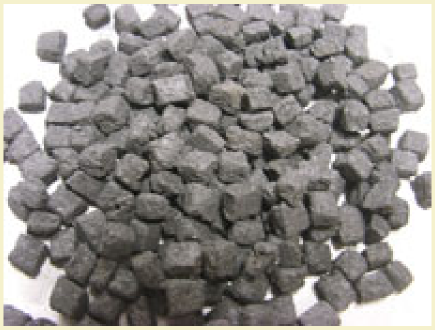

Figure 1: Typical cut stars.

Introduction:
Cut stars are one of the fastest methods of producing stars, and they are used almost exclusively when making small and mid sized color break canister shells. Cut stars have the advantage of being easier to ignite than all other types of stars, since the corners and rough edges take fire easily. They are also popular among hobbyists for their ease of fabrication and the ability to make small batches with minimal waste of composition.

Cut stars also increase a canister shell's resistance to vertical stress loads during lift. Visualize dropping a sack full of bricks compared with a sack full of bowling balls. The sack full of bowling balls (round stars) is more likely to rupture and spill it's contents than the sack full of bricks (cut stars), since square objects can not slide around each other and exert a force against the container walls. If a shell is properly loaded with cut stars and rough powder, the stars would literally have to crush under the pressure before the shell could rupture. This means a shell casing full of cut stars can handle more stress during lift than a shell full of round stars.

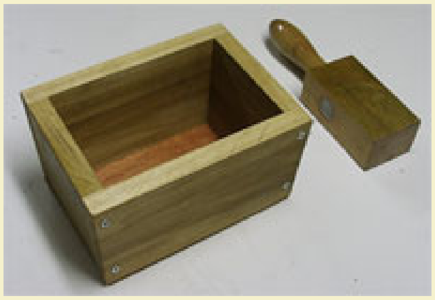

Figure 2: A wooden loaf box and rammer.

Several methods are possible for making cut stars. The one described here is perhaps the most efficient, and is similar to the procedure commonly used in commercial industry. The basic idea is to create a large loaf of composition, then slice off slabs that are the same thickness as the stars you are making. All the slabs are laid out on a table and diced up into cubes. The advantage to this method is that you can make several different sized stars from the same loaf, since all you do is change the thickness of your slices and cut accordingly. This method allows the worker to control the size of the star in all three dimensions, which is more difficult to do with other methods that require one single large slab to be pounded out and cut.

The tools required for this method, which can be made as described in this month's tool tip, include a special tapered box, a heavy rammer and a cutting blade.

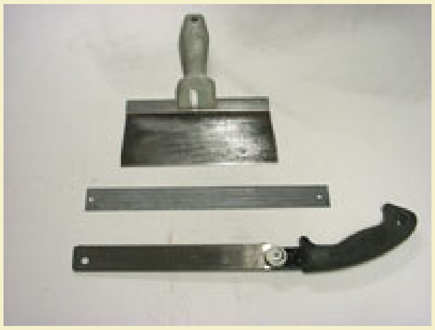

Figure 3: Cutting tools.

Wetting the Composition:
The star composition must first be wet with the appropriate solvent, which is usually water with 10-20% alcohol added. The alcohol helps the star dry faster and breaks the surface tension of the water, allowing the moisture to be incorporated into the powder with less effort. Some formulas require special solvents, such as alcohol/acetone mixtures or NC lacquer. These are more difficult to work with, so it is advised that the beginner start with a formula that can be bound with water/alcohol.

The amount of solvent used varies greatly depending on the composition. Formulas heavy in charcoal, aluminum or parlon will require substantially more solvent than other formulas. A good approach to dampening a new formula is to start with 10% of solution (by weight), work it into the powder good, and then work in additional solvent in 2% increments until the desired consistency is reached.

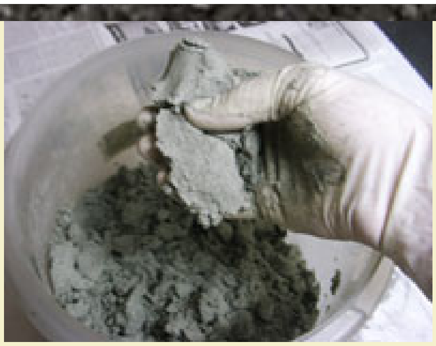

Figure 4: Testing comp for proper moisture content.

The water is worked in by kneading the composition with both hands, squeezing vigorously to force the moisture to distribute evenly throughout the powder. Pushing the damp powder through a coarse screen can also help break up the lumps and distribute the moisture more evenly. Another method is to tamp down the powder in your mixing bowl using your fists until it is one solid mass and let it sit for a few minutes. This allows the moisture to distribute itself through capillary action. Beware that some compositions containing finely powdered aluminum and nitrates can heat up when condensed into a solid mass like this, so do not leave such mixtures unattended.

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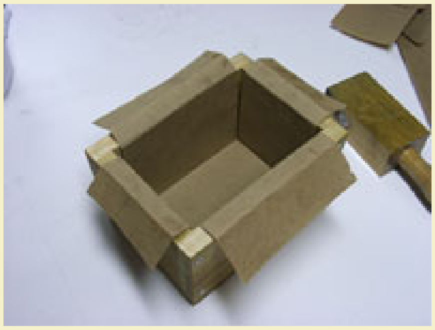

Figure 5: Lining the box with 60lb kraft paper.

Knowing when the comp is damp enough is somewhat of an art in itself and requires experience with cutting various different types of formulas. One rule of thumb for testing proper dampness is to grab a handful of composition, give it a hard squeeze, and then press your thumb into the resulting lump. If the lump breaks into only a few large pieces, then it is about right. If it crumbles, then the comp is still too dry. If the lump has a shiny surface or makes a squishy sound, then it is probably too wet. Sometimes you have to actually pound a loaf and try cutting it before you know for sure. For this reason it is a good idea to take notes when determining the proper moisture content so that you do not have to go through this trial and error every time.

Making the Loaf:

Prepare your loaf box by lining it with two strips of 60 lb kraft paper. The purpose of this paper is to prevent the loaf from sticking to the walls of the box when it is removed. Figure 5 shows the paper liner in place. It helps to tape the overhanging paper to the sides of the box in order to prevent them from getting pushed back into the box during ramming.

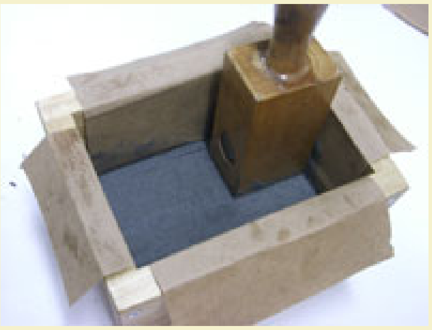

Figure 6: Ramming in the first powder increment.

The loaf will be made in two or three increments, depending on the size of your box and how much composition you have. It is not necessary to fill the box all the way up, but a thicker loaf is more efficient to work with.

Begin by scooping several handfuls of damp comp into the box, such that when it is pounded flat it will occupy a third of the box. The rammer is then used to flatten down the composition as tightly as possible. Spend more time pounding the edges and corners, as this is where the comp tends to be least compressed. If the comp is not compressed adequately, then the stars will crumble when cut, or even when the loaf is dumped from the box. To avoid ripping the paper liner when ramming the edges, which is easy to do by accident, hold the rammer flat against the walls of the box and use it like a guide (see Figure 6).

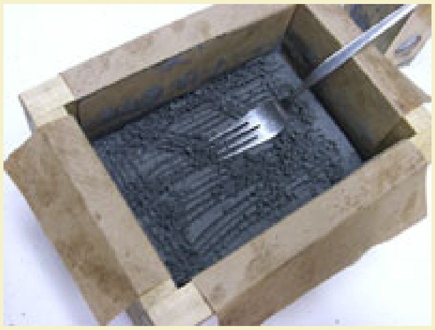

Figure 7: Roughing up the surface before ramming the next increment.

If water pools up on the surface of the comp after pounding for a while, then the comp is probably too damp. You may have to crumble the loaf back up and lay the powder out to dry for a while if this happens. If the loaf gets a little loose and sloppy like jello after pounding, that is normal. But a shiny, wet surface is an indicator that you overwet the comp. An over-dampened loaf will sag while being sliced and also result stars that easily become stuck together during the cutting operation. If the surface of the loaf seems overly solid, the comp may be too dry. If the loaf cracks when it is removed from the box, or if the slices crumble when cut from the loaf, then you will need to crumble the loaf back into your bucket and add more solvent.

After the first layer is completely compressed and smooth, take a fork and scratch some lines on the surface (see Figure 7). This helps the next layer adhere to the previous layer, otherwise the loaf slices could crack where

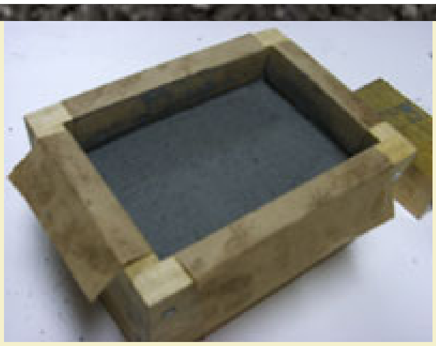

Figure 8: Box is fully loaded.

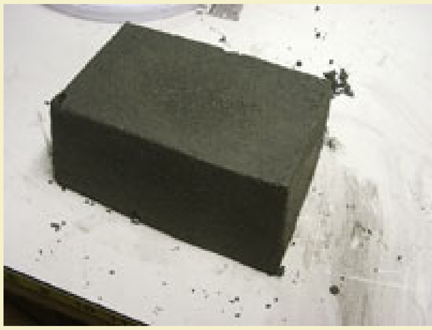

Figure 9: Inverting the box and pulling the paper releases the loaf.

these seams are.

The second and third layers are applied just like the first, using the fork again after loading the second layer. The purpose of loading the box in three increments is to allow better consolidation of the composition. Just as in loading rockets, drivers, or anything else-- smaller increments result in better confinement for a given amount of ramming force. You could load the box in four or even five increments if you wanted to, but three gets the job done with the least amount of work.

The fully loaded box should look like Figure 8. The box is now turned upside down and slapped down onto the table in order to jar the loaf loose. If the loaf is stuck, the paper can be pulled to help free it. Once it is lose it will easily fall out of the box due to the tapered walls. The paper is then removed from the loaf, giving you a nice solid block of composition that should look like Figure 9.

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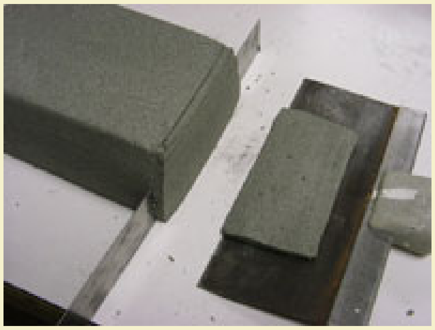
Figure 10: Slicing slabs off the loaf.

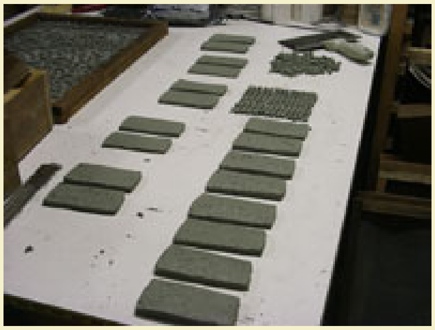
Figure 11: All slabs sliced and ready for cutting.

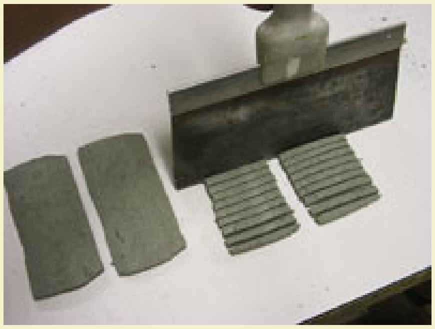
Figure 12: Cutting two slabs at a time with a drywall blade.

Slicing and Dicing:

If you got your loaf out of the box in one piece with no signs of cracks, you are ready to start slicing it. If the loaf cracked or large pieces fell off, you will need to crumple it back into your mixing bowl and work in a little more solvent before repacking it again. Do not add more than 2% additional solvent if this happens, since it is a lot more difficult to remove moisture if you overwet the comp than it is to add more moisture.

The large block of composition is now sliced into slabs that are as thick as the size stars you are making. Care should be taken to make sure that the slices are straight so that the slabs have an even thickness, as opposed to being wedge shaped. I find that the thin stainless steel rulers sold in office supply stores work good for slicing the comp, and come in handy for many other powder shaving operations when making comets, crosettes or plate stars. Sometimes these rulers will have a cork backing that must be removed and cleaned up.

Unless you are dealing with a really cohesive type of composition, don't let the slabs fall over onto the table, rather try to catch them with a wide blade as seen in Figure 10. The blade is then used to arranged the slabs for cutting on a large table, as seen in Figure 11. Arrange the slabs in sets of two, since that is how many most blades will be able to slice at one time.

Since this process makes somewhat of a mess, some builders will lay down a sheet of kraft paper to work on, which gets thrown away in order to save time cleaning up afterwards. When working on paper, it is necessary to work on top of dry prime, as described below.

Figures 12 and 13 show how the slabs are cut into cubes using a drywall blade. The blade edge must be cleaned off periodically to prevent a buildup of composition, otherwise stars will start sticking to the blade while cutting. It helps to slide each row of stars forward after they have been cut in both directions so that there is a gap between them. Otherwise the stars will be too close together, which causes them to get stuck to each other. It also helps to slide the blade just a tad sideways after making a cut, which helps keep stars from sticking to the blade.

If the stars seem to be sticking to the blade, the table, each other and everything else, then they are probably too wet. Allow them to sit and dry a while to see if the problem clears up. If the loaf is like jello and is bulging at the sides, then you should crumble it out onto the table and allow the comp to air dry for a bit. Of course, you will then have to re-line your box and pound the loaf again.

One trick that makes cutting easier and reduces the tendency for stars to get stuck to each other is to lay down a dry prime bedding under the slices, as

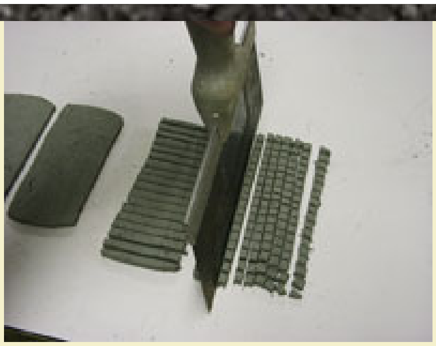

Figure 13: Final cuts should produce evenly sized cubes.

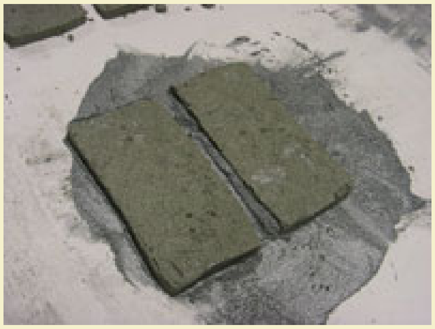

Figure 14: Placing slabs on a bedding of dry prime helps the cutting process.

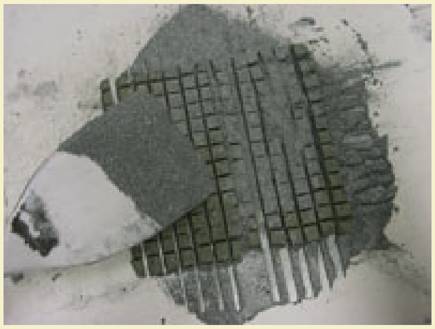

Figure 15: Applying dry prime after cutting helps prevent stars from sticking together.

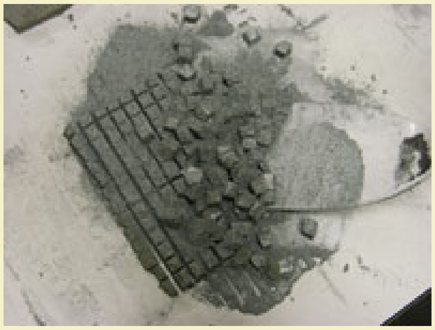

Figure 16: Using a spatula to roll

seen in Figure 14. Since white strobe stars are being cut in this example, the prime bedding is a hot metallic prime that will need a final meal prime coating once the stars are dry. Straight meal can be used on most organic fueled color stars, glitter, streamers and anything else without a high ignition temperature.

Cutting the slabs on top of the prime allows the stars to slide easier when cutting them, rather than sticking to the table. Once the stars are cut, more prime is sprinkled on top of them as seen in Figure 15. This dry prime gets between the cracks and further reduces the tendency of stars to stick together after cutting. A spatula is used to scoop the stars up off the table and flip them over repeatedly to make sure the prime completely covers them.

The primed stars are now scooped onto a screen for drying. Using a large mesh screen allows the loose prime and star chunks to filter through for easy cleanup. The leftover prime can not be reused for much else because it will be contaminated with bits and pieces of the cut stars.

One drawback to the dry prime method is that it does tend to waste a good bit prime when making large batches of cut stars. It also produces a rather thin prime layer. However, a star roller can be used to roll more prime onto cut stars once they are dry.

Making cut stars can seem frustrating at first, but most problems will be caused from conditions resulting from either too much or too little moisture in the comp. Once you find the proper moisture level and record it for your most commonly used compositions, cutting stars gets much easier. You will have to pay your dues at first, swearing at sticky stars that have to be hand separated or crumbly stars that fall apart when scooping them off the table, but persistence will pay off. With a little practice, you may find yourself slicing perfect little cubes faster than a sushi chef in China Town!

stars in prime until they are coated
on all sides.

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Technique... **Page 1**

Working With Paste

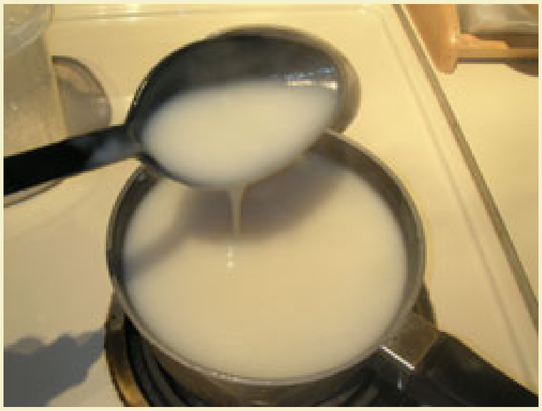

Figure 1: Paste made on a stove top.

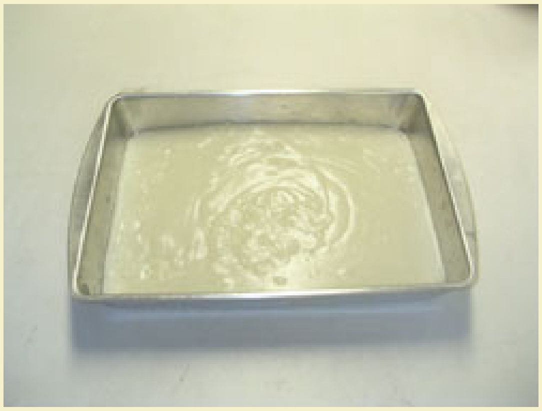

Figure 2: Using an aluminum pan for rapid cooling of hot paste.

Introduction:
When I began making fireworks in my youth, a time when sources of information were very limited and there was no AFN or the internet, I assumed that the "wheat paste" referred to in the traditional texts was simply made by dissolving flour into warm water. While this did make a sort of paste that resulted in harder casings, it performed nowhere near as well as paste made in the correct way as I discovered years later.

The term "wheat paste" generally refers to a type of paste that can in fact be made by simply adding the flour-like substance to water. However, it is not really flour, rather it is an extract from flour that is designed for easy mixing. The most available form of this paste goes by the name Golden Harvest, and is a type of wall-paper paste that can be found in some hardware stores. The same wheat paste packaged under the Golden Harvest name can also be purchased in much larger quantities from PyroSupplies.com. I purchased one of the 40 pound paste bags form PyroSupplies about four years ago and, many many shells later, there is still about 15 pounds left.

Making Paste from Flour:
Traditional paste can in fact be made from common baking flour found in the grocery store. The trick, however, is to boil the water during the process so that the gluten is released from the flour. This is what results in the nice, thick goop that you won't get by simply mixing flour and water together. The procedure for making a typical batch of paste using flour and water is as follows:

1) Boil 3 cups of water in a soup pot.

2) In a blender, mix 3 cups of cold water with one cup of flour.

3) Pour the flour/water mixture from the blender into the boiling water, stirring as they mix.

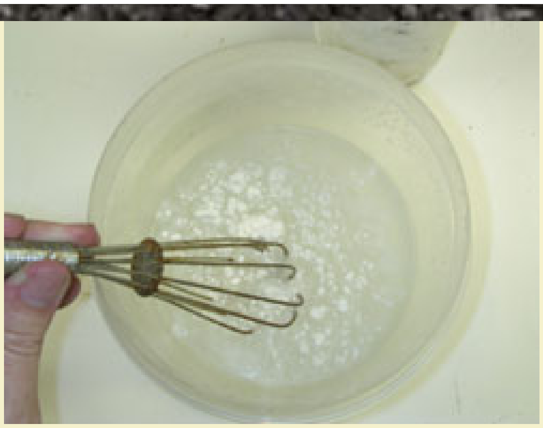

Figure 3: Using a whisk to mix small batches of paste.

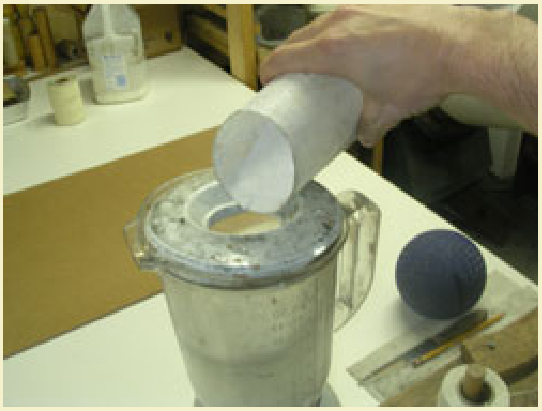

Figure 4: Using a blender to make short work of the mixing process.

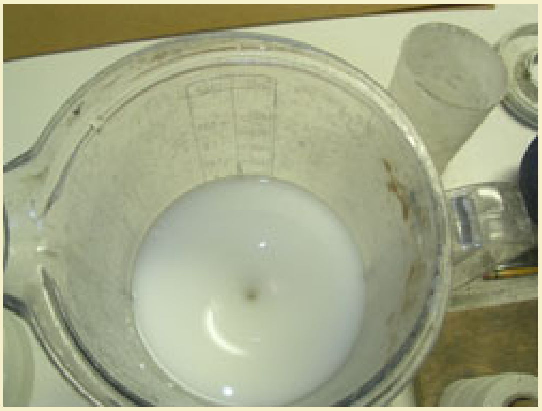

Figure 5: Using the vortex size as a gauge for when the paste is ready.

4) Keep stirring the mixture, making sure the paste does not burn and clump up on the bottom of the pot. At a certain point the paste will begin to get noticeably thicker. The longer you cook it, the thicker it will get.

5) Once the paste has reached the desired viscosity, let it cool and use it right away.

If the paste is allowed to cool in the cooking pot, it will take quite a while. This long wait will result in some skinning on the surface and the paste will become thicker by the time it is ready to use. By transferring the paste into an aluminum pan as seen in Figure 2, the cooling will be much faster due to the rapid heat transmission characteristics of aluminum combined with the increased surface area of exposed paste.

While this paste works just as well as wheat paste, the primary disadvantage is that it is more trouble to make for the hobbyist who typically needs only a small quantity for pasting in a few shells. It is more ideally suited for commercial operations where large pots of paste are cooked and used the same day.

Making Commercial Wheat Paste:
Since the commercial wheat paste can be produced without the need for boiling water, it is ideally suited to small batches. Very small batches can be made by simply using a whisk to stir in the powder and break up the lumps. It is important to add the wheat paste to your water in small quantities when mixing paste in this way, otherwise you will get lumps that are hard to remove. If you live in a humid climate and your wheat paste has a lot of lumps in it, you may need to screen it before adding it to the water, otherwise these lumps are not going to easily dissolve.

A more efficient method of mixing wheat paste is to use a kitchen blender, as seen in Figure 4. The blender makes the mixing process go very fast, and results in a very uniform paste that is completely free of lumps every time. However, a minimum of about three cups of paste must be made when using this technique, otherwise the paste tends to get splattered around the mostly empty blender and doesn't mix well.

The blender method also provides an easy way to tell when your paste has reached the proper consistency, which is the size of the vortex created while the blender is running. When the vortex just starts to disappear, that is usually when your paste will be ready. The procedure for making wheat paste in a blender is as follows:

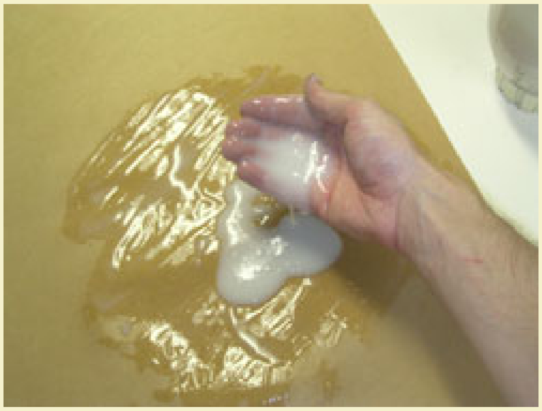

Figure 6: Paste consistency using Golden Harvest wheat paste.

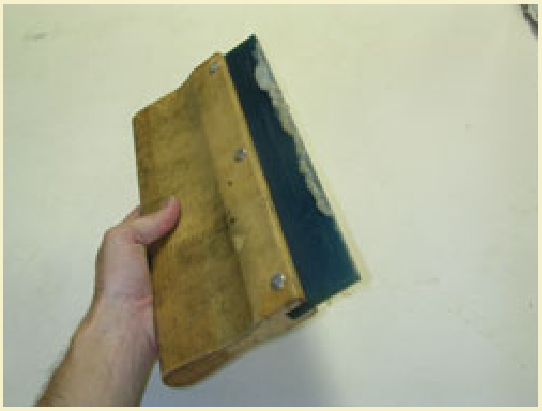

Figure 7: Using a squeegee to quickly clean up the mess from pasting operations.

1) Add 3 or 4 cups of water to your blender. Do not fill the blender more than half full of water.

2) Run the blender on low speed, pouring in the wheat paste through the hole in the lid.

3) Continue adding paste until the vortex disappears, then switch the blender to high speed. The vortex should appear again on the new speed.

4) Continue adding paste until the vortex disappears. At this point your paste will be ready to use.

The desired viscosity of your paste will depend on the thickness of the paper you will be using it on. In general, thicker paper should have a slightly soupier paste, since the paper will absorb a lot of the water. Thinner paper, such as 30 pound outer wraps and crossette wrappers, work well with a slightly thicker paste.

Paste tends to get thicker the longer it sits, so it is best to use it right away after making it. An unfortunate disadvantage of wheat paste is that it can not be stored for more than a day or two before it spoils. Various additives are said to remedy this problem, such as sodium salicylate or paris green, but I have not had any luck with these. Mixing white glue with wheat paste does seem to slow down the spoiling process, but I have seen nothing the completely eliminates it. You are better off just getting used to making only the amount you need, or pasting in all your shells in one batch operation instead of one at a time as you produce them.

Yet another problem with wheat paste is that various insects seem to find it quite tasty. These bugs will not only infest your dry paste storage, but they will even eat your shells after they have been pasted. Some Maltese shell builders have remedied this problem by adding poisons to the paste, such as paris green, which keeps the bugs away. Tight fitting lids on your paste storage will also keep the bugs out of your dry paste.

One final tip: that huge sticky mess left on your workbench after pasting in shells can be easily cleaned up by using a squeegee as seen in Figure 7. A large silk-screening squeegee is shown here, but any variety should work well. Just be sure to cleanup as soon as you are done, or even at various intervals if doing a large job, otherwise the paste will dry on the table and become a lot more work to remove. Simply adding water to dried paste does not turn it back into its original state, so it is best to remove it before it is too late.

Wheat paste is a critical component in fireworks manufacture and is likely to be the paste of choice for quite some time. It is cheap, easy to make, non toxic and very good at producing strong, well sealed shell casings.

Happy pasting!

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Technique... **Page 1**

Making Rough Powder

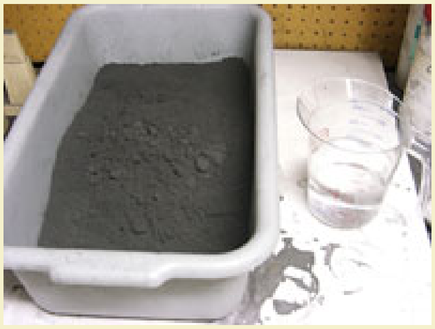

Figure 1: A plastic mixing bucket full of meal powder with 5% dextrin added.

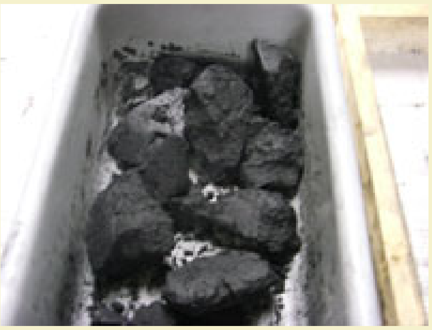

Figure 2: 14% water by weight is incorporated into the powder and formed into big chunks.

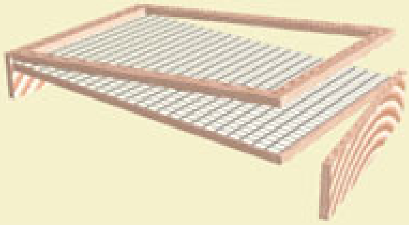

Figure 3: Screen frame assembly.

Introduction:

Rough powder, also called pulverone, is a granular mixture made from black powder that is used as a structural filler in Italian canister shells. It is also used extensively by the Maltese in both lifting and breaking their shells.

Rough powder provides a non-compressible filler in the form of large granules that allow hot gases to pass through it without creating a fire block. It has the advantage of burning away after it serves it's purpose, which is to insure that the shell makes it out of the mortar without rupturing under the lift forces. It also helps to keep shell components in place when used as a filler between gaps or as a hard bedding between different effects layers.

Wetting the Meal:

Rough Powder is usually made from the standard 75-15-10 black powder mixture with an additional 5% dextrin added to make the grains harder. If the rough powder is to be used only as a structural filler, then it need not be made from ball milled powder. Simple green mix will work fine, since the purpose of the powder will be to fill voids rather than contributing to the break charge.

If the rough powder is to be used for building Maltese shells, then a fast burning ball milled meal should be used. The rough powder will be responsible for both lifting and breaking the shell, thus a slower burning green mix will not work well.

Prepare a plastic mixing container full of meal as shown in Figure 1. An amount of water equal to about 14% of the weight of the meal is added and mixed in by hand. Using alcohol mixed with the water is not desirable in this case, even though it makes the job of mixing in the water easier. The powder will develop more lumps if mixed without alcohol, and these lumps help create better rough powder with less fines (small particle dust) created during screening.

To help distribute the water through the meal, it helps to pound all the dampened powder into one large slab after the water has been worked into the mix for several minutes. The star cutting rammer shown here works good for pounding the damp meal into a slab.

The slab is allowed to sit for a few minutes, then it is broken into chunks as shown in Figure 2. If the chunks seem too crumbly when broken apart, then more water needs to be added. If the slab develops a shiny wet surface when pounded out, then the composition is too wet.

Screening the Chunks:

A table is prepared with a covering of newspaper on which the rough powder will be screened onto. This paper helps the powder dry, and makes cleanup easier as well.

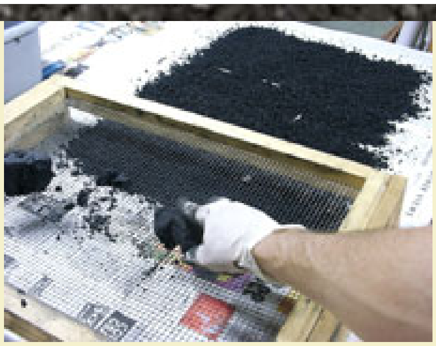
Figure 4: Chunks are pushed through screen, not grated like cheese.

You will need to make a screen from the galvanized hardware cloth sold in most hardware stores. The most common size to use is 1/4" screen, although some builders screen through a 1/2" screen first and then, after the grains dry a little, push them through a 1/4" screen a little while later. This double screening helps reduce the amount of fines. Regardless of your technique, you will probably want 1/8", 1/4" and 1/2" screens for sizing purposes.

The screens can be made by sandwiching the screen between two wooden frames, as seen in Figure 3. The opposing pieces are held together using wood screws, with overlapping joints at the corners. A piece of 1x4 is screwed onto each end of the frame to hold it up off the table. This design, as opposed to a closed box design, allows you to screen long strips of powder without the screen box getting in the way.

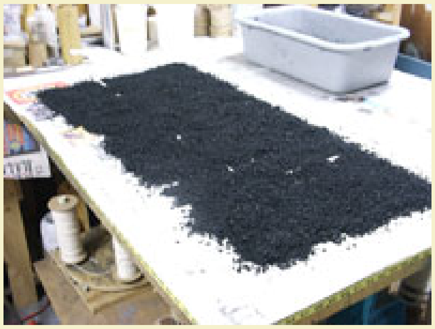
Figure 5: Moving the screen sideways as the chunks are screened results in a thin layer that dries faster.

Figure 4 shows the chunks being pushed through the screen. Avoid the tendency to drag the chunks across the screen, which acts like a cheese grater. This will create flat ribbons of powder instead of the gravel like chunks that are desired. If the powder is properly dampened, the chunks should break apart into small pieces as you push them through the screen. If they extrude into square pieces, then the powder is definitely too wet. If they crumble into dust with little effort, then the powder is too dry.

Screen only enough to cover the paper, then shift the screen over and continue covering the newspaper. Figure 5 shows a strip of completed rough powder left to dry. This can be moved onto a new sheet of paper or onto paper lined drying screens after 24 hours of drying. Trying to move it while wet can cause unwanted clumping.

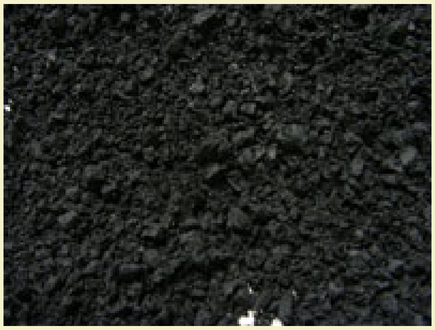
Figure 6: Closeup shows the large variety of particle sizes in the screened powder.

Figure 6 shows the variety of grain sizes in the finished product. If this powder is to be used for constructing Maltese shells, you will need to run the dry powder through a 1/8" screen to separate lift powder from break powder. Everything that passes the 1/8" screen is lift charge, while everything that sits on the screen is break charge.

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Making Black Match

Introduction:
Many methods of making black match have been published over the years, and most of them work with varying degrees of success. I have tried many methods myself, from things as simple as soaking single strands of cotton string in a dish of slurry and hanging them from nails to dry, or as complex as automated match looms that individually coat multiple strands of string and twist them together as they are fed onto a rotating frame. While the idea of an automated machine that churns out black match unattended is always an appealing goal to the mechanically inclined pyro, I have come to realize that simple methods can be used to create a years supply of high quality match in only a few hours worth of work. Thus, it does not make sense for the hobbyist to expend any time on an elaborate device that consumes valuable shop space to do a task that only costs two hours of time per year!

The problem with most match machine designs, which usually pull strands of cotton string through a bucket of meal powder slurry, is that the slurry does not penetrate to the core of the string. This results in match that does not handle bends very well, and tends to lose its rigidity once bent. This is because the outer coating of powder cracks off and leaves just the exposed inner string. While such flaws are more tolerant in piped match, it will likely cause ignition failure in a non-piped application such as fusing drivers, rockets or inserts. The way to determine the quality of a piece of black match is to cut it in half and examine the cross section. If the cross section is white, then the match is really only suited for piped match. If it is black all the way through and does not become floppy when bent, then you know you have some high quality match that will not likely fail.

The method of making "hand made" match shown here was given to me by a commercial manufacturer who makes all his match this way. It is a very simple method, requiring a minimal amount of tooling, yet is still fast and produces the highest quality match I have seen.

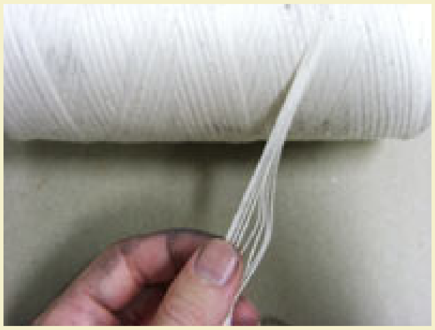
Figure 1: 8 strand cotton string.

Materials:
The most important thing you need for making good quality match is the right string for the job. High quality match typically incorporates multiple strands of a thin cotton twine into one strand of finished match. The individual strands can not be very thick since you will be using between 4 and 12 of them. Thin cross match typically uses 4 strands, while match that will be piped for shell leaders will use between 8 and 12 strands.

While 100% cotton is said to be the ideal string to use for making match, I have also had good results using the mercerized cotton thread found in art supply stores for use in crochet. The thin cotton thread used in the black match industry has the tendency to break very easily when manipulated as single strands, which makes it frustrating to work with. The crochet thread is very thin yet strong enough to handle the tension placed on it while making match by hand.

The best string to use for the particular method of match making shown here comes already grouped in the number of strands that you wish to use. This string comes in large rolls made from flat bands of parallel strands, as shown in Figure 1. This eliminates the need to buy many separate rolls of thread to

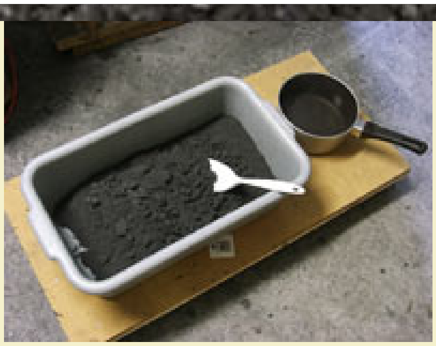

Figure 2: Meal powder and pan of boiling water.

get the number of strands you desire.

The only other material you need for making match is a tub of meal powder with 5% dextrin added. It is highly recommended that the meal powder used be ball milled to a very fine consistency. Using only screened "green mix" can result in slow match that bubbles molten slag as it burns. About 3.5 lbs of meal (1.6 Kg) will make about 400 feet of match. Unlike methods that involve pulling the string through a slurry bucket, this hand method is very efficient with the use of meal slurry, resulting in very little waste.

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Making Black Match...

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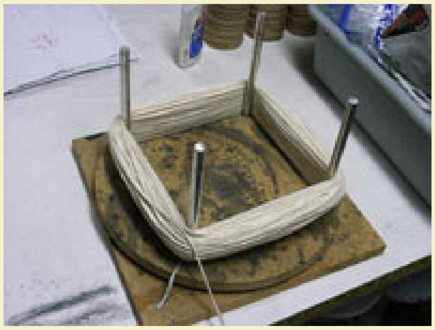
Figure 3: Winding desired length into a circular bundle.

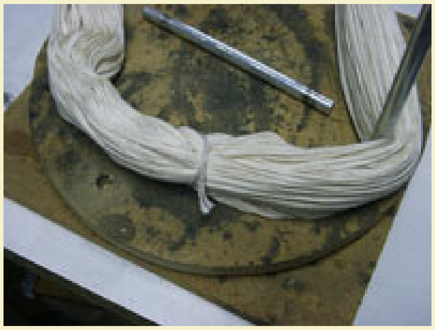
Figure 4: Bundle is removed and both ends are tied around the bundle.

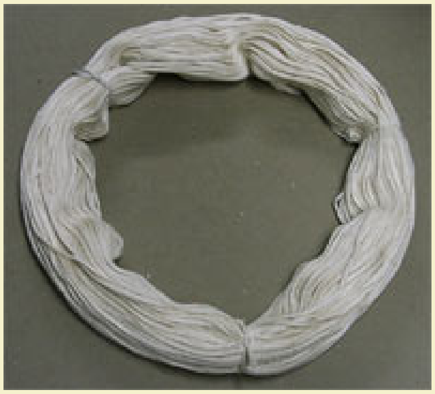
Figure 5: A third knotted loop helps secure the bundle.

Procedure:
First you must prepare all the string you will be using to make the match into a circular bundle. This requires you to know about how much match your frame will hold, and also have a way of measuring out the proper amount of string when you make the bundle.

The device I use for rolling up the string, shown in Figure 3, utilizes a piece of wood mounted on top of a "lazy susan" type roller bearing. Four aluminum rods are press fitted into holes on top of the rotating platform, such that at least one of the rods may be easily removed. The string is tied to the removable rod, then a pre determined number of revolutions is made in order to measure out the string. Making the rods 12 inches on center can make the measuring calculations easier, since one turn will then give you roughly four feet.

If you are using separate rolls of string to get the desired number of strands, you will need to gather the ends together and wind them together as one thick band. If your string is on round rolls, it is easiest just to drop them loosely into a bucket on the floor while spooling from them. String cones are best placed on the floor such that you are spooling the string off them from above. Cylindrical rolls of string will have to be placed on rod fixtures that allow the rolls to spin freely as you take string from them.

Once the proper amount of string is transferred to your winding jig, remove the loose pin and tie the starting end of string that was tied around the rod into a loose fitting band around the string bundle, as shown in Figure 4. This band should be loose enough that you can fit your fingers under it without much effort.

Now the string is removed from the winding jig and the remaining loose end is also tied around the bundle as before. Tie a knot in the end of this string so that it will be marked as the end of the roll, which will be the end that gets tied to the frame when you transfer this string onto the match frame.

An optional third band may be tied around the string bundle at this point, as shown in Figure 5. The purpose of the two or three string bands is to prevent the bundle from becoming hopelessly entangled during the meal saturation process. As long as these bands are in place to insure that the strands of the bundle do not cross over on themselves, then entanglement will be prevented.

When preparing the meal slurry, the use of boiling water helps incorporate the already milled ingredients to a still finer level of contact. If you are not using ball milled powder, then the use of boiling water is definitely recommended.

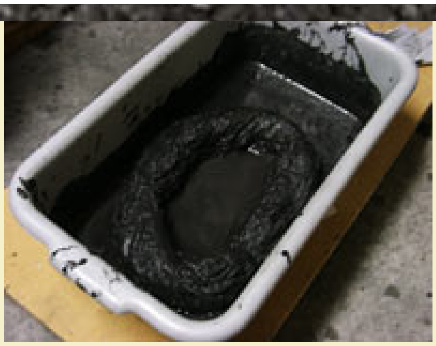

Figure 6: Soaking the string in the meal slurry.

The water should be slowly added to the powder and incorporated with a spatula until a muddy consistency is obtained. This is perhaps the trickiest part of the process, since too much water will result in less powder on the finished match, while too little water will make it difficult to work the slurry into the string. One test for an overly wet batch is to rock the bucket and create a wave that bounces off one side. If the wave bounces off the side and travels back across the full length of the slurry, then it is too wet. The slurry should be thin enough that it runs off your spatula easily, but thick enough to deaden the propagation of any waves created in the slurry.

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Making Black Match...

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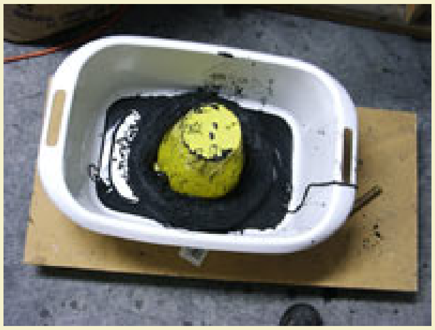

Figure 7: Saturated string placed over a core to prevent entanglement.

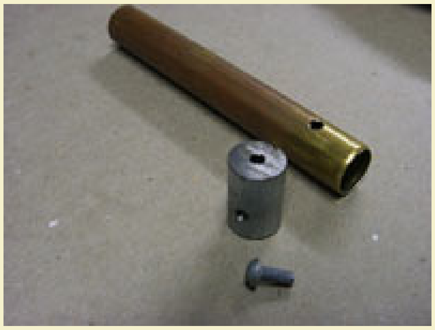

Figure 8: Sizing die used to control diameter of finished match.

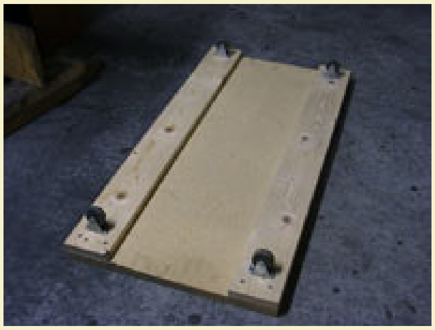

Figure 9: Roller board used to keep the string bucket aligned with the frame.

The bundle of string is now placed into the slurry bucket and worked with both hands. This is also a critical step of the process and, if not done correctly, could result in white spots of uncoated string when wound onto the frame. Spread the strands of the bundle apart and scoop the slurry into the inner parts of the bundle. Special attention must be given to the areas under the tie bands, since that part of the bundle can not be spread open.

Continue to work the slurry into the string for several minuets or more. The longer you knead the powder into the core of the strings, the better the match will be. Pick the hoop up and crush it down on its edges while rotating it. Continue this process until no more white string can be found when prying into the inner layers of the bundle.

The saturated string is now removed and placed over a tapered core such as a small bucket or an orange road construction cone. This tapered center piece will allow the string to be unwound without crossing over and getting entangled. It is my experience that once you have an entanglement at this stage, you will most likely not be able to straighten it out and will have to discard the whole mess and start over. As long as there is a central core that the string can not slip under, then entanglement will not occur.

The string and core should be placed in a container to reduce the mess it will create when unwinding the string, as shown in Figure 7. At this point it is safe to cut the three retainer bands that secure the bundle. Locate the knotted string that marks the ending point of your coil and unravel a few feet off the coil so that it will be ready to tie off to the frame.

Before going onto the match frame, the match must pass through a sizing die to shave off any clumps of slurry that would result in irregularities on the surface of the match. A simple sizing die can be made with a length of brass tube and an aluminum plug that fits in one end, as seen in Figure 8. The aluminum plug contains the size hole that is desired, which is 3/16" for the 8 strand match being made in this example. A threaded hole in the side of the die allows different dies to be inserted into the tube and held in place with a set screw. The brass tube should be about five or six inches long so that it can easily be held in one hand as the match passes through it.

Another tool that makes the process easier is the roller board shown in Figure 9. The bucket of wound match sits on this board as it is being wound onto the frame. The wheels under the board, which are fixed position casters, allow the match bucket to easily slide side to side when winding the match onto the frame. One foot can then be used to keep the bucket in line with the frame as the match works it's way across the frame width.

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Making Black Match...

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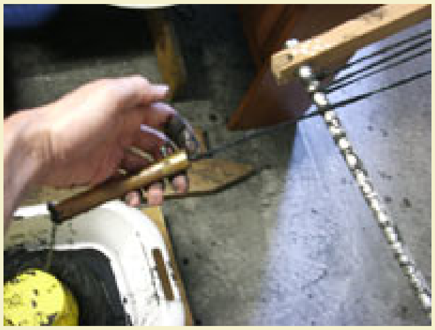

Figure 10: Fuse runs through die and onto frame.

The end of the match is first passed through the sizing die, then tied off to one corner of the match making frame, as seen in Figure 10. One hand is used to hold the sizing die and guide the match onto the frame, while the other hand slowly rotates the frame (see Figure 10). Try to keep enough tension on the match to keep it from shifting out of place as the frame rotates. The match should be spaced onto the frame with at least a half inch between parallel strands in order to avoid strands from contacting each other and sticking together.

The match bucket should be positioned close enough to the frame so that any slurry that drops out of the sizing die will land in the bucket. The sliding platform previously mentioned helps the operator keep the bucket under the sizing die during the whole process.

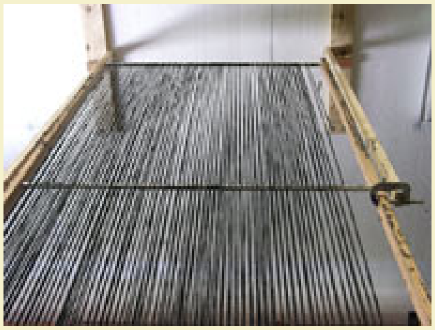

Figure 11: Match frame fully loaded.

Once the match frame is fully loaded, a C-clamp can be used to hold it upright and keep it from spinning. The match is allowed to dry on the frame for several days before removing it. Snip a small piece from the end and check the core for dryness before removing all the match from the frame.

Be sure to examine and test your match for integrity before putting it into use. There should be no large crystals of nitrate visible, no white string exposed and the match should not bend easily. Ideally there should be a thick enough coating of powder on the string so that the individual strands of string are not easily noticeable.

The match can be tested by selecting a sample from the thinnest looking strand in the batch and running it all the way through a hole drilled in a thick piece of wood. The match should take fire easily and maintain a consistent burn rate through the hole and out the other side.

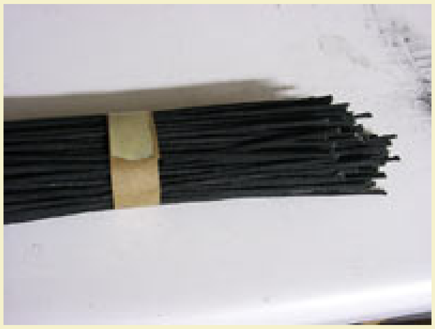

Figure 12: Finished match, bundled and ready for storage.

Burn rate should also be tested by igniting one foot long pieces of match in open air. If the match sputters along, occassionally stops and then restarts, then the coating of powder on the string is not thick enough. The most common mistakes when learning to make match is to use a slurry that is too thin or failing to work the powder into the core of the string.

Once the match is completely dry and tested, remove it from the frame by first cutting all the ends at the bottom with an anvil cutter. Then the match is cut from the top while using one hand to prevent them from dropping to the floor. Try to avoid bending the match at this point. It is best to remove small handfuls of match at a time and lay them out flat on a long table.

Once all the match is removed from the frame, it is bundled together using bands made from strips of paper. This will keep all the pieces in a secure bundle, making it possible to move the bundle without bending any match. The bundle should not be so tight that individual sticks of match can not be slid out for use. Many hobbyists store their finished match in long tubes of paper or PVC with removable caps at both ends.

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Technique...

Materials:

(1) 50 gallon oil drum
(1) 20 gallon oil drum
(1) approximately 50 lbs of white pine (or other wood)
(1) pile of scrap wood for fuel
(4) fire bricks

Tools:

Circular Saw and metal cutting tool such as Jig saw with metal cutting blade, torch, air chisel etc.

November, 2001 Issue

Tool Tip:

Modify your anvil cutter with a length gauge.

Gallery:

Pictures From PGI 2001.

Technique:

Learn how to make your own charcoal.

Introduction:

Making your own charcoal might sound like one of those obsessive endeavors engaged in by the hard core pyro who is bent on fabricating everything from elemental raw materials. Given the fact that some pyros are actively growing their own forests of paulownina trees for the sole purpose of harvesting them into charcoal, perhaps it really is a fringe activity within a fringe activity. Considering that commercial charcoal can be purchased for as little as 30 cents a pound, is it really worth the effort?

Well, anyone who has ever put 4-5 hours into fabricating an 8" ball shell that could simply be purchased for $20 is obviously motivated by something other than saving time and money. It's the nature of any good hobby to provide the hobbyist with ever increasing avenues of exploration. Activities such as making black powder, making charcoal, making raw match and even making your own chemicals are all challenging endeavors within the overall field of pyrotechnics. Persuing these specialties will not only increase your knowledge of the finer details of firework making, they will give you increased control over those details.

Once you see a spider web shell or gold comet made with your own hand-crafted pine charcoal, you may never want to go back to commercial "air float." If you desire to make your own BP for lift and burst charges, then it becomes even more important to use the specialty charcoals such as willow, maple or grapevine to get the most force per ounce out of your powder.

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Making Your Own Charcoal...

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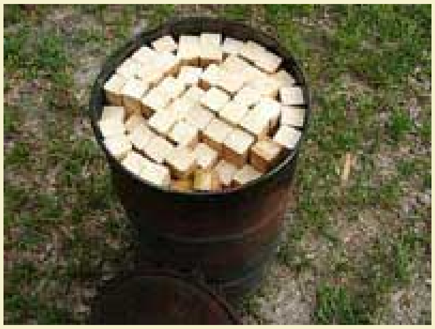

Figure 1: Pine 2x2s packed into the drum.

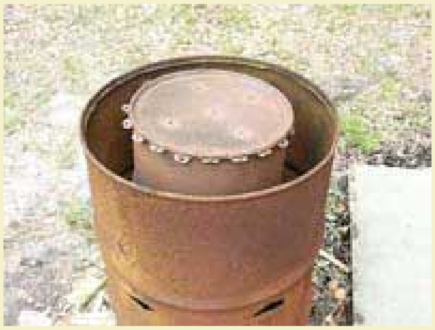

Figure 2: Drum loaded into the furnace.

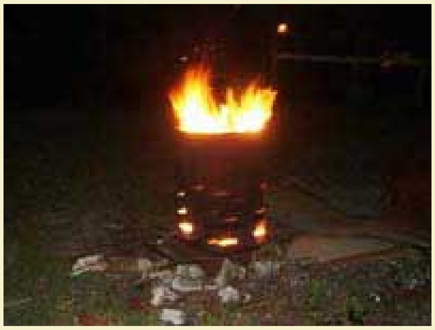

Figure 3: Fired up!

Building the Kiln:
The basic idea behind the method of charcoal making shown here is to isolate some sticks of wood in a fireproof container that is minimally vented to allow gases to escape during carbonization. A fire is built around the container until the internal temperatures reach between 600-1000 degrees where the carbonization process begins. Heat is maintained around the barrel until the carbonization process has completed, which takes about 3-4 hours depending on how dense the wood is packed and how quickly the reaction temperature is reached.

The size of the system described here will allow batches of charcoal ranging from 10-15 lbs, depending on what kind of wood is used and how densely the drum is packed. The design is based around the widely available steel drums used to ship oil, transmission fluids and other lubricants. Both a 50 gallon and a 20 gallon steel drum are required, which are often obtainable from your local oil distributor for around $10 and $5 respectively. Make sure that you get the lid that goes on the 20 gallon drum.

Once you have acquired the two drums, the first step is to cut the top out of the 50 gallon drum. I did this using a saber saw with a metal cutting blade, while some people use a cutting torch, air chisel etc. Make sure to cut inside the lip the way a can-opener would, since cutting the side would leave a hazardously jagged lip on the barrel. On completing the circumference of your cut, the lid will drop to the bottom of the barrel, which is as good a place for it as any.

You will also need to punch four or five 1/4" vent holes in the top of the 20 gal. drum lid. This is not exactly necessary, since the gasses will be able to escape from around the sides of the lid, but the yellow flames that will fire from the top holes make a good indicator for the progress of the carbonization process. You can drill them or simply hammer a center punch through the lid.

Next you will want to clean the oil and other debris from the insides of both barrels, as well as cut some vent holes at the bottom of the 50 gal. drum. You may use the same cutting tool you used on the lid to cut some large holes at the bottom of the barrel, or you can simply make several cuts in the side using an ax when the barrel is red hot (see Figure 3. for the ax-cut results). Keep in mind that larger holes will reduce the strength of the drum and cause it to buckle from rust and heat damage quicker than several smaller holes.

The quickest way to clean both barrels is to build a fire in the 50 gal. drum until it is blazing hot, then remove the lid from the 20 gal. drum and invert it into the fire. This will burn away all the oil residue from both barrels (along with the paint). Remove the gasket from the 20 gal. lid and toss it into the fire for cleaning as well. If you are are using the ax method to vent the 50 gal.

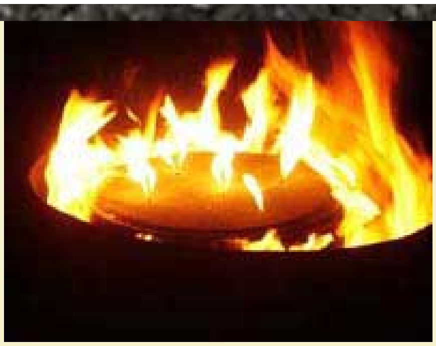

Figure 4: Volatile gases burn bright yellow as they exit the drum.

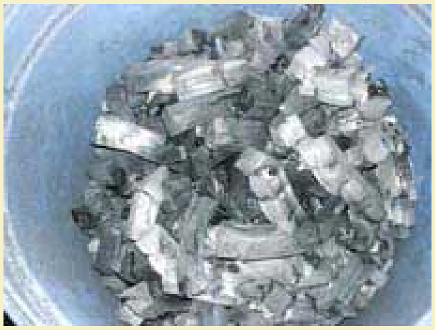

Figure 5: Finished product ready for grinding.

drum, now is the time to start gashing the sides. The red-hot metal will allow the ax to slice through much easier than if the barrel was cold.

The final step in completing the furnace is to place a few fire bricks in the bottom of the 50 gal. drum in order to hold the 20 gal. drum up off the bottom. Do not use cinder blocks or other porous type brick, as they will crumble after the first burn. Using sticks of rebar inserted through holes in the sides of the 50 gal. drum to form a platform for the 20 gal. drum will result in the rebar bending under the weight as it heats up and loses it's strength. The simplest and most reliable method is the use of fire bricks placed in the bottom to hold the drum about six inches off the floor so that hot coals will settle underneath of it.

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Making Your Own Charcoal...

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Selecting the Wood:
Now that you have a furnace for making charcoal, you have any kind of charcoal you want at your disposal. Willow, paulownia, grape vine, maple and plum are all very excellent for making black powder. However, obtaining these types of wood in any usable quantity for making charcoal can be difficult. Varieties of willow can be found growing wild in some areas, but there is a bit of work involved in cutting them down, stripping the bark, splitting them into thinner sticks and then drying them out. Maple can sometimes be found by dumpster diving around cabinet shops, if you are lucky enough to find one nearby that allows such activity on their property.

I have personally found that spruce, a white pine commonly used for house framing materials like 2x2s up to 2x8s, make excellent spark producing charcoal as well as suitable lift and burst charge. The abundant supply of "white wood" scraps at lumber yards, construction sites and even cabinet shops makes this an ideal source of charcoal fodder. Home improvement stores like Home Depot and Lowes will often bundle up their unusable lumber stock of warped wood and sell it very cheap. The larger lumber yards tend to put aside all their scraps and sell them to commercial mulch manufacturers, and they are usually not interested in selling small quantities to individuals.

It is important not to mistake yellow pine for spruce, as the yellow pine is denser, heavier, sappier and does not work as well. The yellow pine can be recognized by a yellower color, more distinct grain and heavier weight. It is usually employed for trusses and larger framing materials such as 2x10s and 2x12s.

While some people go through the effort of removing all knot holes from their wood before turning it into charcoal, I have not found this to be worth the trouble. If you simply avoid wood with large knots and ignore the small ones, the ratio of knots to wood is so low that it does not effect the final charcoal performance. What is important, however, is to try and get the wood stock into thinner sticks not much larger than two inches in diameter. The thinner the wood stock is, the faster it will convert to charcoal. Placing large chunks of 2x4 into the barrel will result in long burn times and possible incomplete carbonization due to the insulating property of wood.

If your source of scrap wood comes in larger sizes like 2x4s and up, then it is easiest to cut them into foot long segments and then use an ax to split them into smaller pieces. It takes 50 lbs of wood to generate 15 lbs of charcoal, so the more wood you can fit into your drum the better. However, very dense arrangements like that shown in Figure 1 will result in longer burn times to reach complete carbonization. The drum in this case was loaded with three rows of 2x2s cut to about 7 inch lengths. This required about thirteen 8 ft long 2x2s to fill the drum, so if you would rather just go buy the wood in a convienent size rather than spend the time searching for scraps and cutting them up, your cost would be roughly one dollar per pound of finished charcoal.

Fire Up the Furnace:
Once you have your drum loaded up with the wood of your choice, snap the lid on and place it into the center of the furnace barrel as shown in Figure 2. It is not necessary to bend the tabs down on the lid, as you want a rather loose fit for the gases to escape. The space around the center drum is then filled with wood scraps, cardboard, leaves or anything else that will burn. A pile of leaves or other fine, dry material helps get the initial fire going, after which larger chunks of scrap wood can be added to keep the fire going with less maintenance.

Another method to getting started is to build a blazing fire in the large drum before inserting the smaller drum. Let the fire burn down to glowing coals, then throw the small barrel in on top of them. This makes it easier to get the initial fire going and provides a nice hot coal bed under the wood drum. Scraps that are dropped around the sides of the inner barrel will then easily ignite on their own.

If the fire appears to have ghostly thin, dark orange flames that get sucked down into the fire space, then there is not enough ventilation to feed the fire. Take your ax and make more holes, twisting the ax head in order to open up the slices wider so more oxygen can feed in. You will need bright orange flames around the entire peripheral of the drum to ensure even heating.

It will take about 30 to 60 minutes of a roaring fire before the pyrolysis of the wood will begin. The first indication of the reaction will be white smoke pouring out from the lid of the drum. This will then give way to the hissing of volatile gases that ignite on exit to form bright yellow flames as seen in Figure 4. Once these flames are seen coming from the top of the drum, the carbonization process is under way. This process actually generates heat on its own, so once it starts you can cut back on the amount of wood fed to the furnace. Simply keep enough wood to keep a moderate fire going until the yellow flames are no longer seen coming from the drum lid, which should take around three hours.

Once the yellow flames disappear, douse the furnace fire with water and allow the drum to cool for about six hours. If you are worried about oxygen getting into the drum and turning your new charcoal to ash, you may cover up the holes with a wet piece of wood, but I've never had a problem with the charcoal igniting inside the drum unless the lid is opened right after the burn is complete.

Processing the Results:
So now you have a nice drum full of charcoal sticks that should look something like Figure 5. The sticks should easily snap in half if they are fully carbonized. You may notice that the sticks at the edges of the drum are a little more crumbly than those at the center, due to hotter temperatures at the sides. If you can't break some of the sticks in the center, then the carbonization process did not complete and there is still wood at their core.

Now there is only one problem left to surmount: how to get these big chunks into a useable powder! This is a messy process no matter how you do it, but the easiest way is to use a large cement-mixer type ball mill with baseball size media in it. The balls do not need to be too heavy, as the charcoal is very easy to crush. My own method involves the use of a home made stamp mill (to be documented in a future issue) that repeatedly drops a round-bottom boat anchor into a metal bowl set in concrete. The bowl is filled with the raw charcoal and beat on for 15 minutes, which is all that is required to turn 90% of it into a fine dust of various particle sizes. I save whatever passes a 30 mesh screen, then return the coarse leftovers back into the next stamp mill load. A standard gallon size ball mill can even be used to break up coarse chunks. Some people even pound the coals by hand, but that would be quite tedious and even more messy than the automated methods. You just have to get creative here, depending on what your mechanical skills are. One could even try putting all the charcoal in a garbage bag and stomping it into powder!

Using the 30 mesh screened charcoal as-is to make comets and streamer stars result in very long tails due to all the various mesh sizes contained in the mix. Ball milling the streamer mixes will result in very dense and bushy tails. When used to make black powder, this charcoal will produce superb meal for use in black match, star primes, driver compositions and grain powder compareable to commercial lift. It's great stuff!

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Technique...

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Mixing with Screens

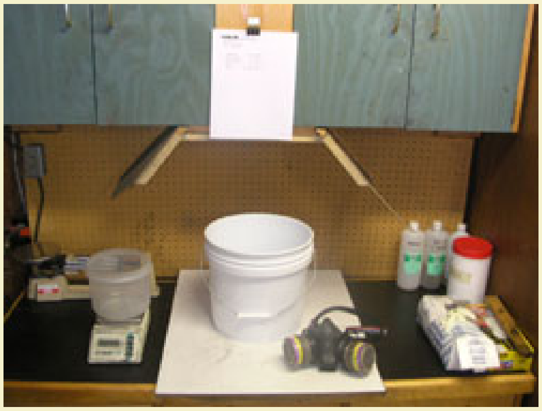

Figure 1: A weighing station for weighing out the components before mixing.

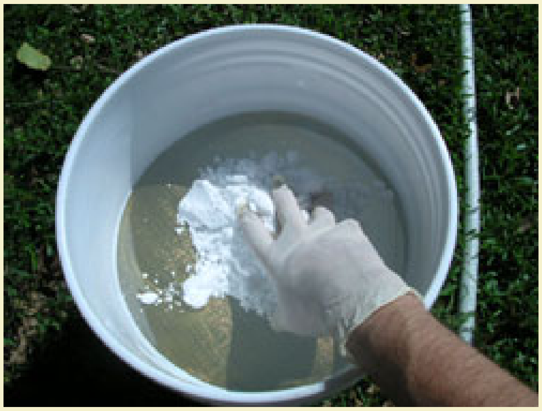

Figure 2: Running individual components through the screen.

Introduction:
The most quick and effective way to mix pyrotechnic compositions together is to pass the ingredients through a screen several times. Most common pyrotechnic mixtures do not need to be finely ground together into an intimate mixture, with meal powder being one of the few exceptions. Almost all star formulas are mixed by screening except in cases where friction sensitivity makes screening prohibitive. Even sensitive mixtures are often partially screened, leaving out one of the chemicals responsible for the sensitivity to friction and then mixing it in by hand afterwards.

This article describes the basic procedure for screening that all beginners need to become familiar with before proceeding to make pyrotechnic devices. The screens shown here can be made as described here.

Preperation:
The first step to producing a pyrotechnic formula is to weigh out the proper amounts of each ingredient that is required. Formulas are specified in parts by weight rather than by volume, so a scale is required. The units measured by the scale are arbitrary, so any type of scale will work as long as it is accurate in the range you intend to measure. For example, mixing black powder requires 75 units of KNO3, 15 units of charcoal and 10 units of sulfur. These units can be pounds, ounces, grams or whatever you want to use.

The parts in a formula can be scaled up or down if desired, as long as they are all multiplied or divided by the same number. So the black powder example could also be 7.5 pounds KNO3, 1.5 pounds charcoal and 1 pound sulfur. Scaling in the other direction and changing units, we could have 750 g KNO3, 150 g C and 100 g S.

The easiest way to scale your formulas up or down in order to obtain a specific batch weight is to use the auto-calculated fields in the formula database found on this website. Entering a value in any field of the formula will auto-calculate the correct values for all other fields. The most typical scenario is to enter the total batch size you want to mix, then let the calculator scale all the individual component weights. The resulting formula sheet is then printed out and used as a reference when mixing.

Figure 1 shows a weighing station where chemicals are weighed out and added to a mixing bucket. Note the central clip holding the single formula to be mixed (a passfire formula printout, naturally!). Avoid mixing from tabular formula lists that display multiple formulas in a single table, as this greatly increases your odds of weighing out the wrong value by looking at the wrong column.

It is often a good idea to screen the individual ingredients separately before screening them all as a group. This is because many oxidizers have clumps that need to be worked out, and occasionally you will get something so hard that it will not pass through the screen. You will then have to weigh this chunk and replace it with an equal weight of chemical that will pass the screen. Other chemicals like parlon or charcoal frequently have large particles that are too big to fit through the screen and must be discarded and replaced if necessary.

The use of rubber gloves is a good idea when screening chemicals, and is mandatory if the chemicals are poisonous or toxic. I prefer disposable latex gloves which can be purchased in boxes of 100 for about $10. These can be rather thin and will tear at the finger tips if you don't keep your nails cut though. Some people prefer thicker rubber gloves that are reusable. I prefer to just throw the disposable gloves away each time rather than having to clean the gloves afterwards. This hobby generates enough of a mess to be cleaned as it is, no need to add another item to the cleanup pile!

A respirator is another mandatory item, even for non toxic chemicals like charcoal. While charcoal and aluminum are not poisonous, they are very fine particles that easily become airborne and can damage your lungs. The respirator you use should be high quality with removable filters and a rubber mask that fits snug with no gaps. To test the air tightness of your respirator, place your hands over the ends of the filters to block the airflow then try to breathe in. You should not be able to suck in any air. This is a good test to perform before using the respirator each time, as the exhaust valve can sometimes get stuck open and render the mask useless.

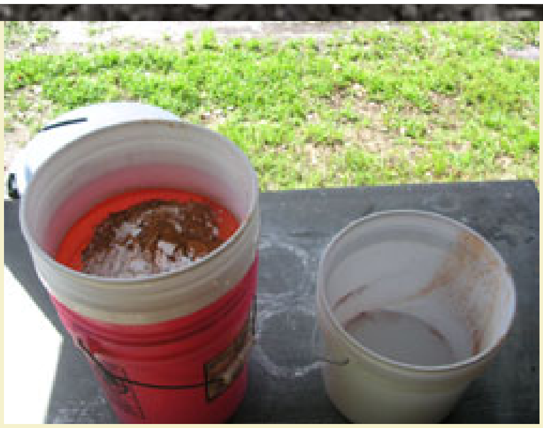
Figure 3: Alternating between two buckets when screening with a bucket screen.

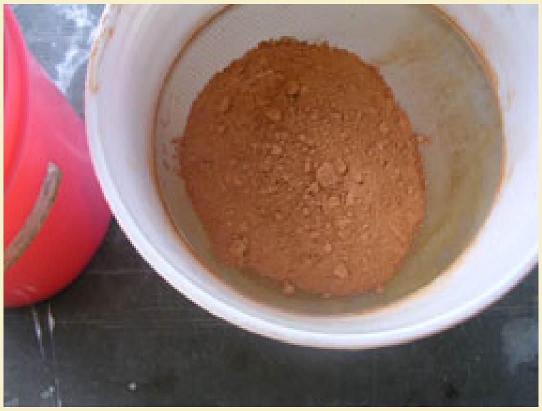
Figure 4: Screened chemicals after one pass through the screen.

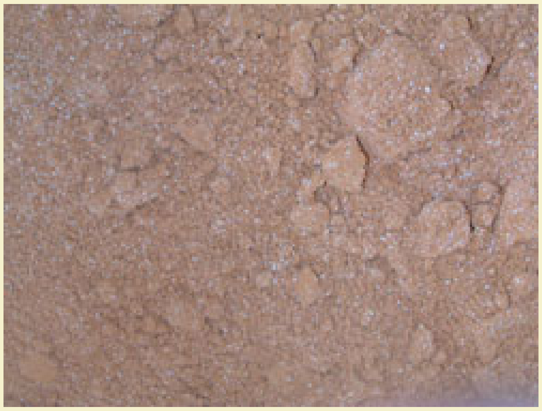
Figure 5: The white specs of stubborn strontium carbonate particles remain after screening is complete.

More...

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Mixing with Screens...

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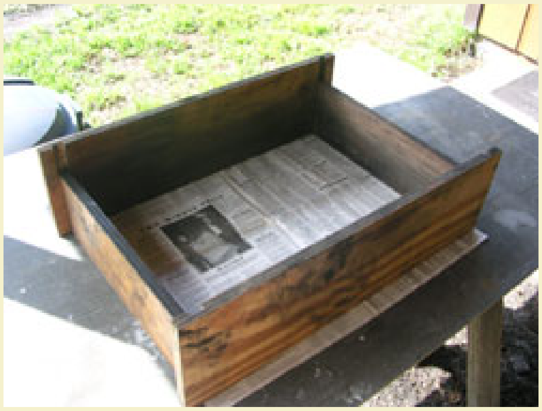

Figure 6: Screen box placed on a sheet of newspaper.

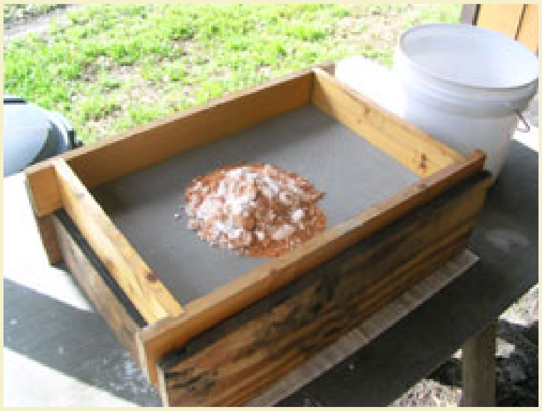

Figure 7: A one pound batch of composition ready to be pushed through the screen.

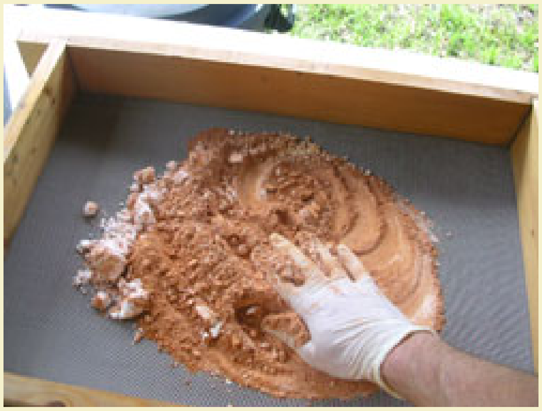

Figure 8: Pushing the chemicals through the screen with a gloved hand.

Mixing:

Figure 3 shows a typical setup when mixing with bucket type screens. Two five gallon buckets are used in conjunction with a screen made from the top of a 5 gallon bucket. Material is poured from one bucket into the screen and screened into the other bucket. Then the screen is placed onto the empty bucket and the process is repeated.

The powder is pushed through the screen using your palm in a circular motion, tapping the screen with your finger tips occasionally to get clogged material to drop through. If you are screening a very large batch, you may not be able to fit the entire batch into your screen all at once. In this case you can screen the powder in several increments.

Figure 6 through 9 shows the setup for screening with a box type screen. The screen box is placed on a sheet of paper to catch the material falling through the screen, then the screen itself is placed on top of the box. The larger working area of the box screen makes it easier to work with compared to the smaller bucket screens, even when screening small batches. Once the material is pushed through the screen, the box is lifted and the newspaper is used to transfer the material back into a container for the next screening.

Because screening is such a dusty process, it must be done outdoors to avoid making a mess in your shop. It helps to work on a table because this is a rather tedious process that is not easy to do sitting down on the ground.

Screening is so effective at mixing the chemicals that you typically do not need to push the chemicals through the screen more than three or four times to get a good mix. Figure 4 and 5 shows how well the chemicals have mixed after just one pass through the screen. Note the small white specs of strontium carbonate in Figure 5. These are tiny clumps that seem to be a typical characteristic of strontium carbonate, and they will not go away regardless of how many times you screen the material. Some people ball mill the strontium carbonate to reduce

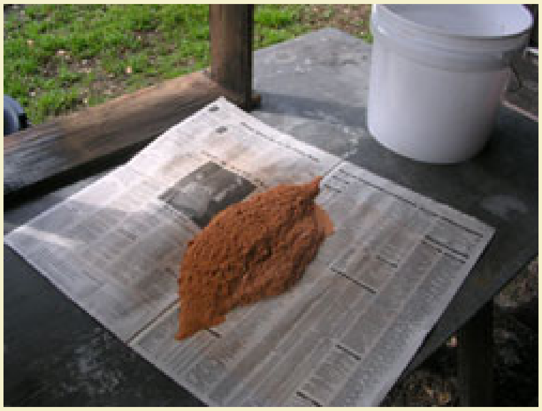

Figure 9: Screend powder is transferred back into a bucket using the newspaper.

these tiny clumps, but they do not seem to effect the performance or quality of color, so most people just leave them as-is with no consequence.

If you are mixing a formula that contains a large flake component such as flake aluminum or coarse charcoal, you will have to leave out the coarse material and screen everything else. The coarse material is then stirred into the batch by hand after the other components have been screened together.

NOTE: Never screen Flash or any other perchlorate or chlorate compositions containing fine powdered metals.

If you have a perchlorate or chlorate formula that contains a fine powdered metal such as magnesium or dark aluminum, screen everything but the metal and then mix the metal in using the diaper method or by stirring it in by hand.

The diaper method of mixing a formula looks similar to Figure 9, with the powder to be mixed sitting on a sheet of paper. The powder is then rolled back and forth and turned in on itself by pulling up the corners of the paper. This produces much less friction than screening and is the only safe way to mix flash compositions.

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Volume 5, Issue 1

Determining Paper Grain Direction

by **Doc Ferguson**

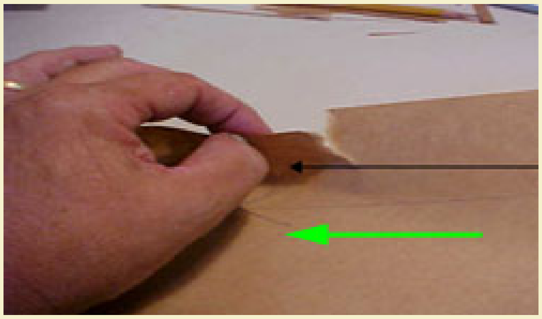

Figure 1: Jagged tear when tearing against the grain.

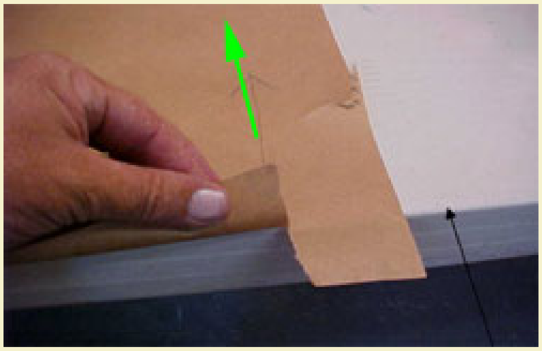

Figure 2: Straight tear when tearing with the grain.

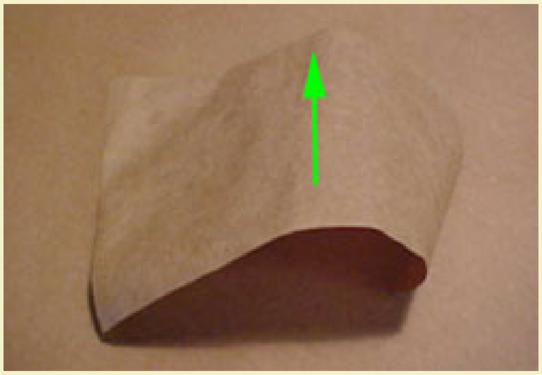

Figure 3: Wetting the paper to determine grain direction.

During the process of manufacturing paper, the fibers within the pulp become predominantly oriented in one direction. This results in a physical characteristic of the finished paper known as the "grain direction" of paper. In fireworks manufacture, it is often important to know what direction the grain is running when making casings. Rolling a shell casing with the grain running the wrong direction can cause heavier multi-break shells to flowerpot during lift, so grain direction is an important thing to be aware of.

This article describes several methods for determining grain direction for a given sample of paper. In all photographs, the green arrow represents the grain direction of the paper.

Tear Method

This method relies on the characteristic of tearing to determine paper grain. Paper that is torn across the grain, as seen in Figure 1, tends to tear in an irregular fashion. However, if the same piece of paper is torn with the grain, as seen in Figure 2, then the tear is much straighter. Thus the direction in which the paper tears the straightest is the direction that the grain is running. This method does not work as well with recycled kraft, since the grain does not seem to be as strongly oriented in recycled paper. Recycled paper tends to tear irregularly in both directions.

Wet Method

The wet method of grain detection operates on the fact that paper expands more across the grain than it does with the grain when wetted. Thus if a piece of paper is wetted on one side, the paper will curl such that the valley of the curl runs parallel with the grain direction, as seen in Figure 3.

Folding Method

The fastest and most reliable way to determine grain direction is by simply folding a sample of paper in both directions, taking note of which axis folds with the least amount of resistance for a given amount of pressure. Figures 4 and 5 show the same sample of paper receiving about the same amount of bending force in two different directions. Figure 5 shows the direction that yields the most to bending, thus revealing the grain direction as shown.

The folding method does not even require a small sample to be cut, you can simply make a small fold on the edge of a large sheet and still get a feel for which direction bends the easiest. This method works equally well for both virgin kraft and recycled kraft, with the example sheet in Figures 4 and 5 being 60 lb recycled kraft.

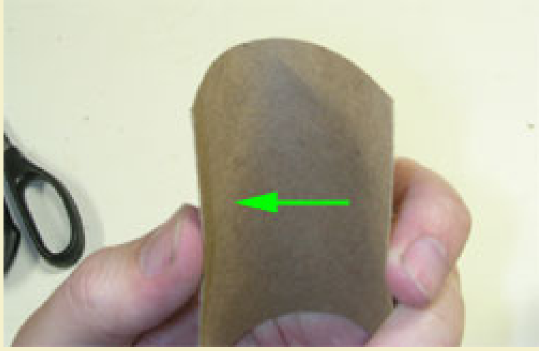
Figure 4: Folding against the grain.

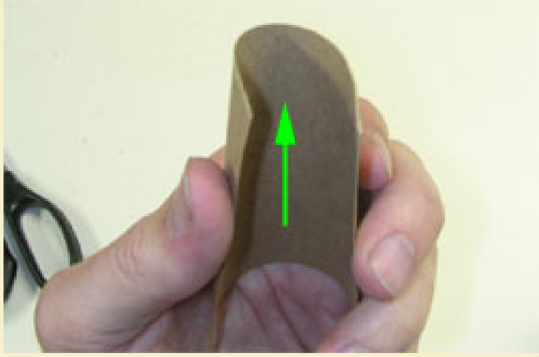
Figure 5: Folding with the grain.

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Tool Tip... **Page 1**

Adding a Torque Wrench to an Arbor Press

An inexpensive way to get consistency in drivers and rocket motors.

Arbor presses are relatively cheap ($50 or less when on sale) and can be a great tool in the Pyro workshop. Pressing a driver or rocket motor with an arbor press can be faster and easier than with hydraulic presses and, while the arbor press has limitations, it can be used effectively for most smaller items. Their biggest drawback is that they depend on 'power by Armstrong' and getting consistency of pressings can be somewhat tedious. An easy way to solve the problem is to modify the press so that a cheap torque wrench can be used to gain consistent grains of fuel in smaller devices.

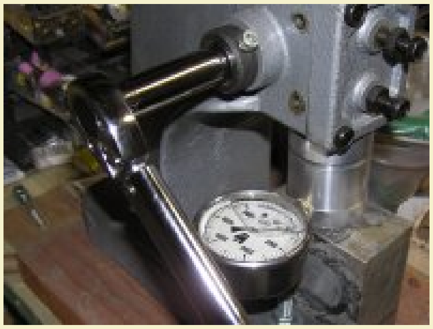
Figure 1: Torque wrench mounted to left side of arbor press shaft.

The first step to modifying the press is to evaluate the best way to install an adaptor (a bolt) so that a torque wrench will fit. Usually, one side of the press has a collar that releases a shaft and allows the arbor press to be disassembled. In the one pictured here, the shaft is easily drilled out and threaded to accept a bolt which can be grabbed by the torque wrench.

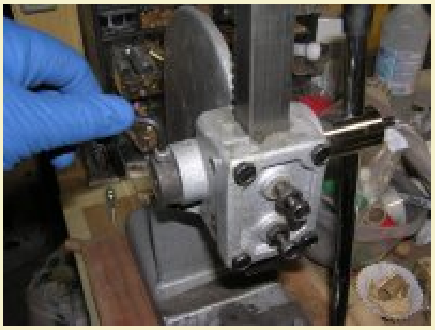
Figure 2: Remove the holding collar on the arbor press shaft.

A hand tap is used to thread the drilled out arbor press shaft. For most cases, a 1/2" thread (either NF or NC) should be used. The torque rating on a 1/2" NC Grade 8 bolt is about 110 pounds and that should be sufficient for most needs. Smaller bolts could be used if you are careful not to exceed the torque ratings when using the adaptor.

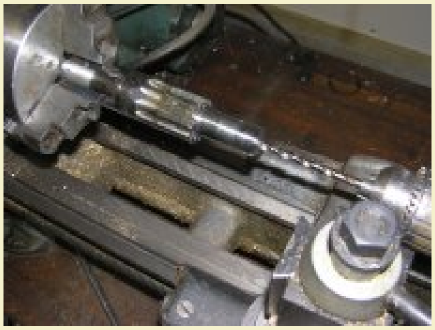
Figure 3: Drill out the shaft to accept a 1/2" tap. In this case, a 27/64" drill was used after a pilot shaft was made with a 1/4" drill.

To drill out the shaft, you do not need a lathe as seen in the picture. You can secure the shaft in a vice and drill a 1/4" hole as the pilot hole with a good electric hand drill. Then redrill the hole with the proper size drill for your tap. A 1/2" NC tap takes a 27/64 drill. Make the hole about 1 1/2" deep and use about 1" of it for threads. Use a 1/2" NC Grade 8 bolt that is about 1" long.

If you already have a torque wrench then you are almost done. If not, then buy one from a discount tool house. You should be able to get one for about $20 or so. A 3/8" drive should allow a torque range from about 10 to about 100 foot pounds of torque and would be sufficient for our purposes. Do not use the beam type wrench since it is almost as bad as using none for our purposes. A beam torque wrench has a pointer that moves along a face plate and indicates torque. Probably the best wrench to use is a 'click' type - also known as a micrometer torque wrench. Set the wrench each time you use it and set it back to zero when you are done. The pictures on the left

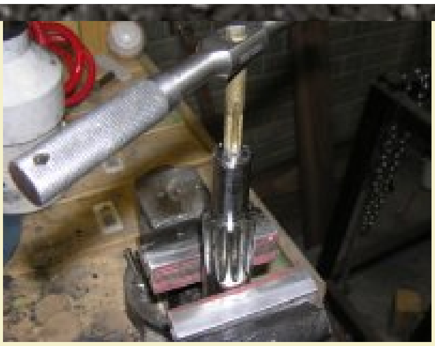

Figure 4: Use a hand tap and carefully cut the threads. If you've never tapped something before, the secrets are to use lubricant, keep things aligned, and go slowly. Cut a quarter turn and back the tap out and repeat. WD-40 will work for a tap lubricant.

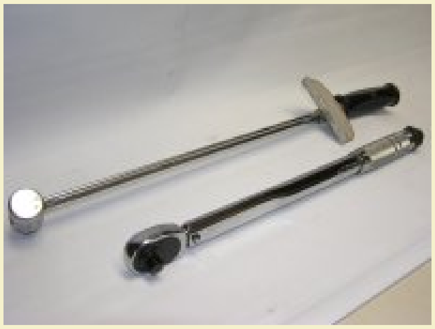

Figure 5: The top torque wrench is the 'beam' type and the bottom wrench is a cheaper micrometer type. The bottom wrench is the most suitable for our project.

show both a beam and 'click' type wrench.

Arbor presses vary in the ratio of movement of the press bar to movement of the ram that is used to press the composition. The one I have is a 20:1. This ratio is a guideline and a 20 pound force on the handle does not necessarily mean 400 pounds will be reflected on the ram. However, the aim here is consistency rather than precision measurement and we can use the ratio as a general guideline and have good success.

Once your bolt is attached to the press shaft and the press is reassembled, you can calibrate the press (if you wish) and start pressing up consistent rockets. I usually use a 40 foot pound rating for a 1/2" motor and get great results in whistles and BP rockets. Keep the size of your motors to 5/8" or less and you should have good success.

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6" Crossette Canister Shell

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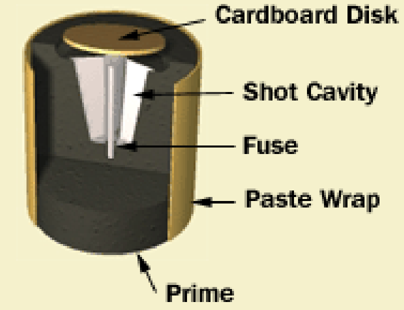


Figure 1: Basic crossette components.

Introduction:
Crossettes, also called split comets, are a special breed of comet that split into four pieces midway through their trajectory. Figure 1 shows a cross section of a typical crossette, which reveals an inner cavity where a high-energy break charge is placed. The comet is pasted in on the sides and top so that it can only burn from one end. When the flame front reaches the inner cavity, the burst charge blows the remainder of the comet into four pieces (ideally).

The inner cavity of a crossette is usually a tapered hole with the profile of a four pointed star or square. Although it is possible to make crossettes with a rounded cavity, the weak points caused by a four pointed polygon help insure that the comet breaks into four equal sized pieces. The taper is neccessary to ease the removal of comets from the pump after pressing, where they are fragile and prone to cracking.

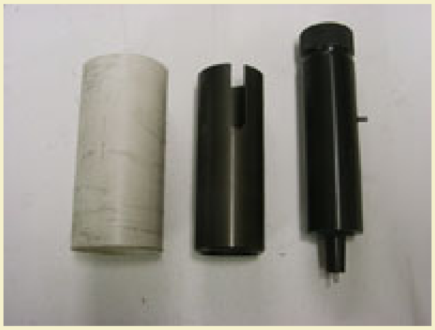
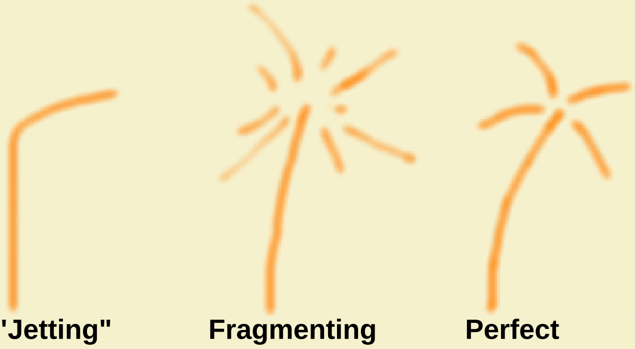


Figure 2: Crossette pump and PVC sleeve.

Crossette shells typically suffer from two problems: crossettes that don't break properly and crossettes that don't all break at the same time. The first step in making a crossette shell is to make sure your crossettes break properly through repeated testing from a star gun. The illustration below shows two of the most common crossette failures seen when testing individual crossettes.



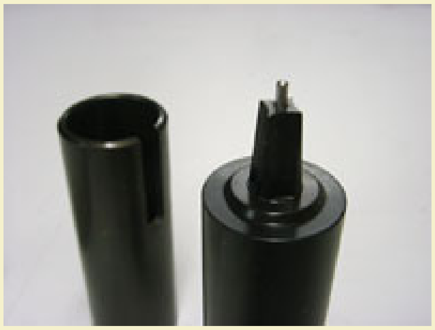


Figure 3: Star shaped cavity former with pin at tip.

Jetting is the most common problem and can be caused by a number of factors. It most often occurs when testing from a star gun, since the setback from the lift can compact the break charge into one side of the cavity and turn the crossette into an end burning rocket. This is why it is important to test your crossettes from a star gun rather than just placing them on a post or hanging them from a string. Star guns create the actual conditions your crossettes will experience when being thrown from a shell, whereas other methods do not and may lead you to think that your crossettes are working only to find that many of them fail when fired from a shell.

The use of too little or too weak of a break charge can also cause jetting. Since the cavity can not hold much powder, a high strength flash type mix must be used. The types of aluminum used for the flash will effect it's strength, with Indian Blackhead being the strongest, followed by German Black and then American Dark.

Another method some builders prefer is to hand roll small firecracker-like "shots" that fit into the cavity, thus insuring that the charge will have adequate confinement to split the comet apart. I personally find that this method adds too much work to a component that is already a lot of work as it is!

The most common trick to eliminate jetting is the use of a fuse that inserts into a small hole at the bottom of the cavity. Most commercial crossette pumps have a pin at the end of the plunger, as seen in Figure 3, which is designed specifically for this purpose. The flame front will reach the small hole first, allowing ignition of the cavity while there is still some composition left at the bottom to help create containment. The passfire fuse, which runs the full length of the cavity, also helps eliminate the end-burner problem by providing a fire gap through any comp that may otherwise get compacted from setback.

Thermolite is the most common choice of passfire for the small inner fuse, probably because it is one of the few types of fuse that is thin enough to actually fit into the hole. However, Thermolite is quite expensive and is increasingly hard to find. I have not had much luck with thin diameter visco fuse as an alternative, as the burn rate is too slow.

My personal secret is the use of hand rolled Chinese paper fuse made from corning dust. This type of fuse is ideal since it is thin, takes fire easily and is very fast burning. For those of you who don't make black powder, corning dust is the fine grained dust leftover when granulating BP. It ranges in particle size from meal to 60 mesh and burns quite rapidly when made into tissue fuse. Corning dust could also be made from pulverizing commercial BP by hand, or screening dampened meal through a 40-50 mesh screen. The procedure for making Chinese paper fuses can be found here.

The other common crossette defect is an overly hard break that causes many small pieces instead of four large pieces. This is a simple matter of dialing in the strength and amount of break used in the crossette. The paste wrap around the crossette should also not be too thick. Two turns of a light weight 30-40 lb kraft paper is all that is required.

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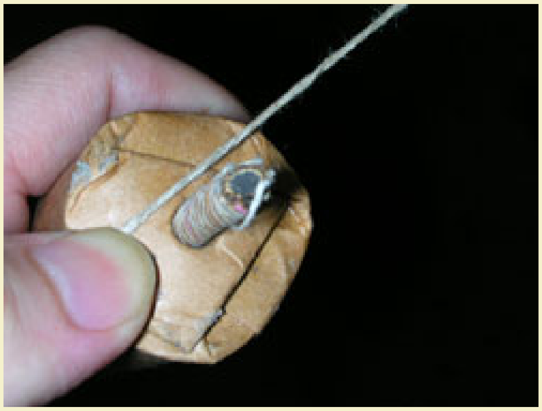
Technique... **Page 1**

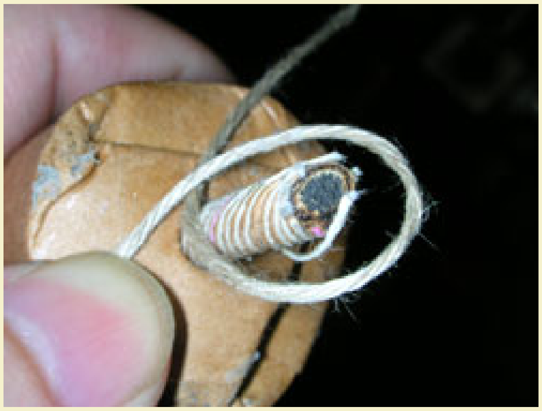
Tying Clove Hitch Knots

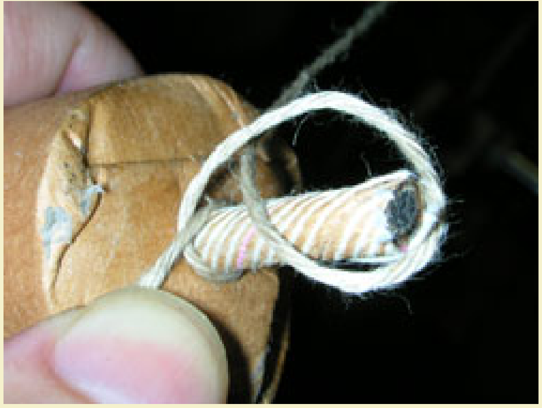
Introduction:
The clove hitch knot might as well be called "the fireworks knot," since it is used almost exclusively among firework makers. There are several features of this knot that make it the ideal choice for use in fireworks. It is a self-cinching knot that stays put once it is pulled tight. Tying a clove hitch is not a two step process like the more common double half hitch knot, which is prone to loosening while tying the second half hitch over top of the first. After the knot pattern is setup, you just pull it once and it is done. Sometimes it is more reassuring to tie a half hitch on top of the clove hitch to make sure it doesn't unravel, but in most cases this isn't necessary.

There are several ways of tying this knot, which are illustrated below. There are probably even more ways of tying it than shown here, but these methods are the most common and will get you tying knots like a pro.

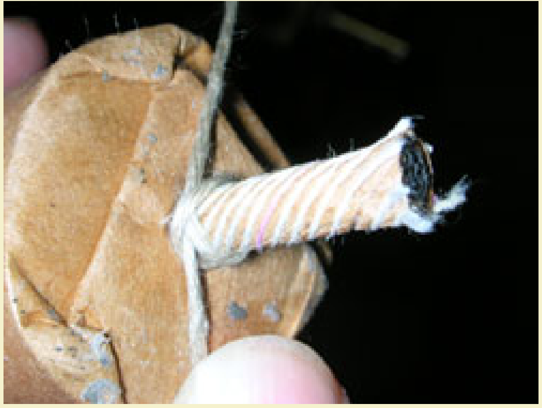
Method #1
One of the biggest advantages of a clove hitch is that it can be tied without having access to the free end of the string. As seen in the sequence below, simply twisting two loops in succession over the top of the time fuse will create a clove hitch knot. Not only is this the fastest method, it also produces the tightest knot. Since the string is being held by a spiking horse, the operator can put his weight into tightening each of the two loops, creating a very tightly cinched knot.


Step 1: Start with the string to the left of the time fuse.


Step 2: Turn a loop by twisting the string in a clockwise direction.

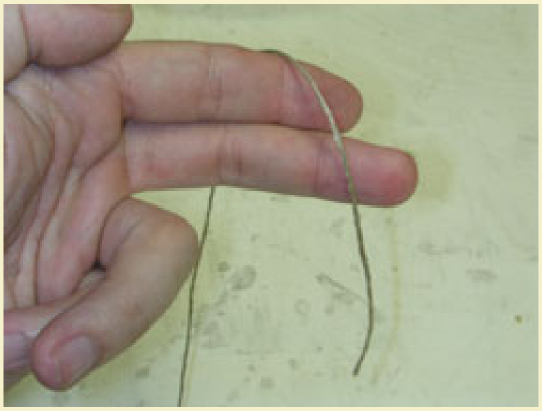


Step 3: Cinch the first loop and then turn a second loop.

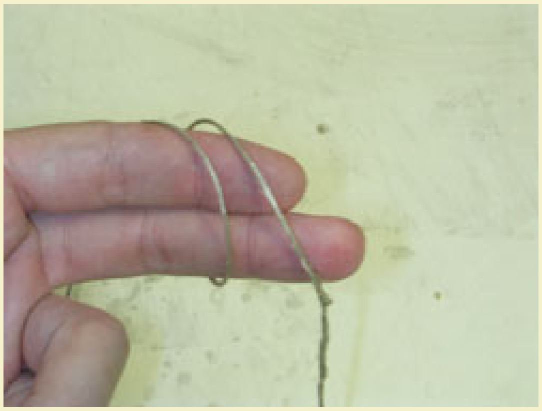


Step 4: Cinching the second loop completes the knot.

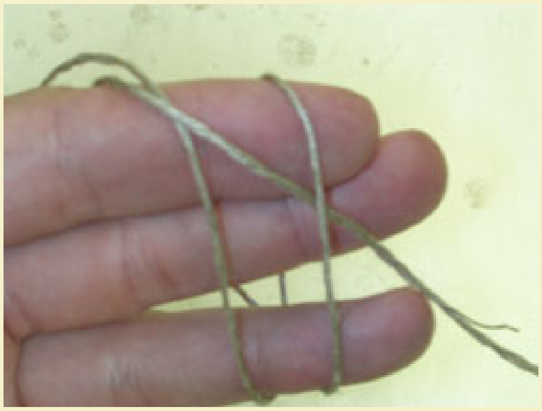
Method #2
While method #1 is ideal for tying off to time fuses when spiking shells, it can't be used in cases where the loop can not be easily passed over the object you are tying onto. The method below shows how to wrap the string around the object being tied such that a clove hitch knot is constructed. This method also works good for pre-tying the knot onto your fingers and then slipping it off so that it may be put in place around nosing paper or other object that is to be cinched closed at a later time.



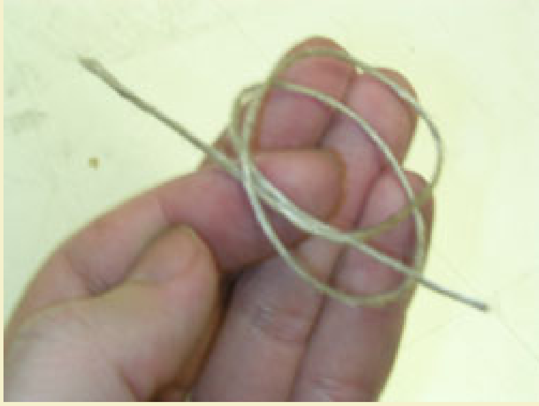
Step 1: First loop finishes on the right.



Step 2: A second loop also finishes on the right.

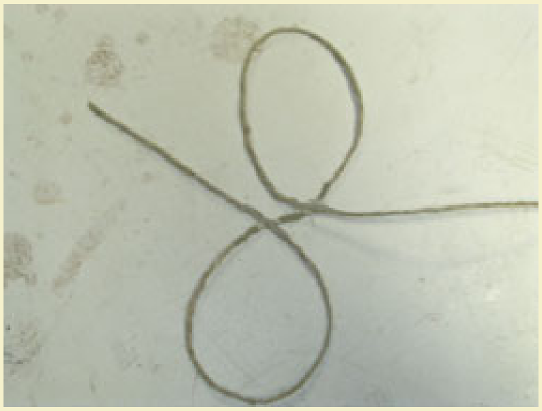


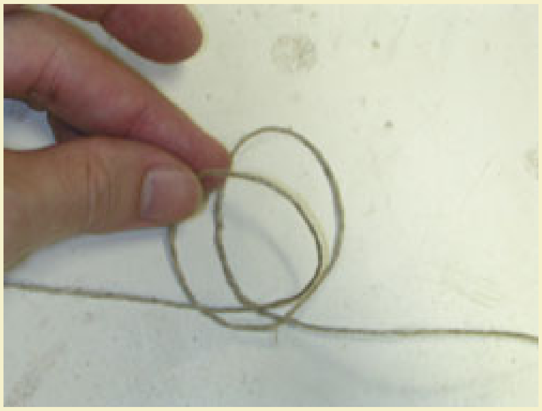
Step 3: The third loop cuts across behind the first two and emerges on the left, then skips over the first loop and finally cuts under the second loop.

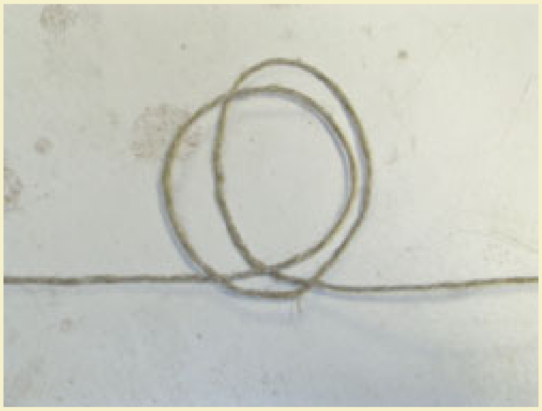


Step 4: If tied around your fingers, the finished knot can be slipped off and placed around whatever needs cinchin'.

Method #3:
This method is not very common when making fireworks, but is used frequently by sailors when tying off to dock posts. The self-cinching feature of the clove hitch is ideal for boat tie-offs, since the more a boat tries to drift away then the tighter the knot gets. This method makes more sense when using a large piece of rope, but is cumbersome with tiny strings.


Step 1: Two opposing loops are twisted in opposite directions.


Step 2: The loops are folded together to form the clove hitch pattern.


Step 3: The hoops are then placed over the object being tied and the two ends are pulled.

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Technique...

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Pumping Stars with Star Plates

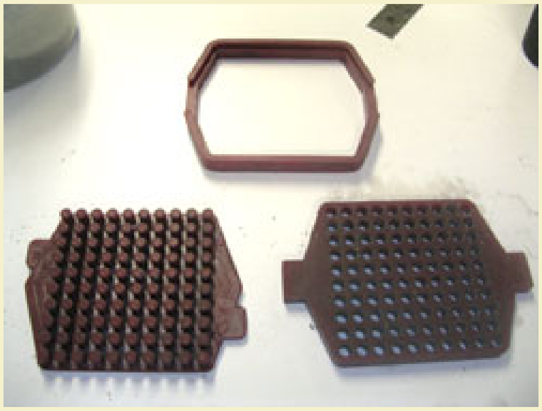

Figure 1: A low cost 3/8" plastic star plate.

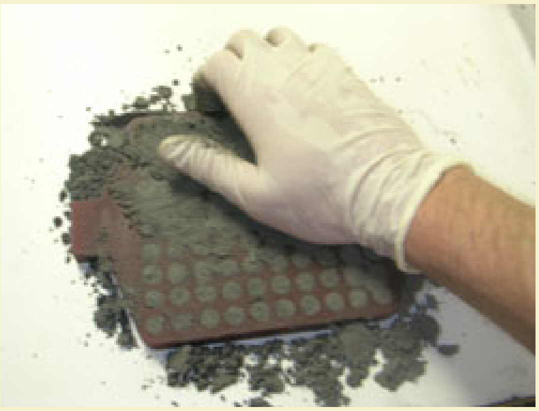

Figure 2: Pushing damp comp into the plate cavities.

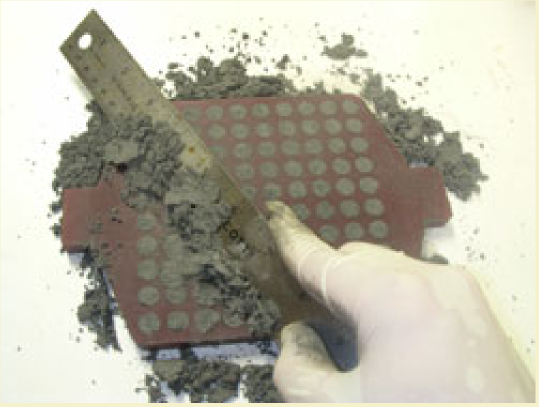

Figure 3: Shaving off excess comp with thin

Introduction:
Pumped stars have several unique advantages for certain applications, and the proper tools can make them quick and easy to produce in relatively large quantities. The cylindrical shape of a pumped star still provides a fine edge around the top and bottom, making them easier to ignite than round stars though not quite as ignitable as cut stars. When produced correctly, size uniformity is easier to obtain than with cut stars or round stars. The cylindrical shape is also ideally suited for fitting into tubes for such uses as roman candles, comets, scatter stars etc. Like the cylindrical shell in a mortar, a cylindrical star to be fired from a tube results in less blow by than a round star, thus the star will travel farther for a given amount of lift charge compared with a round star. For the beginner, quality pumped stars produced with a star plate are also easier to make than both cut stars and round stars.

While large pumped stars (comets) are often produced one at a with a single sleeve and piston, such a practice would be far too tedious and time consuming for producing the larger quantities of smaller diameter stars, such as those used to build a typical color shell. For producing many pumped stars at once, a star plate is used. This is a simple plate full of holes with a matching plate full of pins, as seen in Figure 1.

Two methods of using star plates are demonstrated here, each with advantages and disadvantages.

Method 1:
Figure 1 shows a plastic 3/8" star plate that will produce 100 stars per pressing. These used to be available at Skylighter some years back for a reasonable price, but I have not seen them around lately. While this type of plate is somewhat flexible and not quite as nice as a machined aluminum or brass plate, it is also several hundred dollars cheaper to obtain. The other alternative is to make your own plate, as described here.

metal ruler.

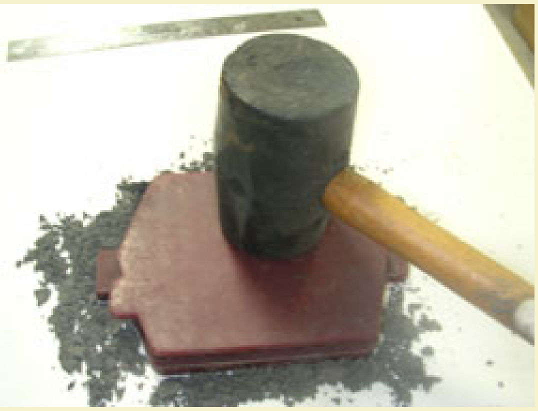

Figure 4: Compacting comp with top plate and rubber mallet.

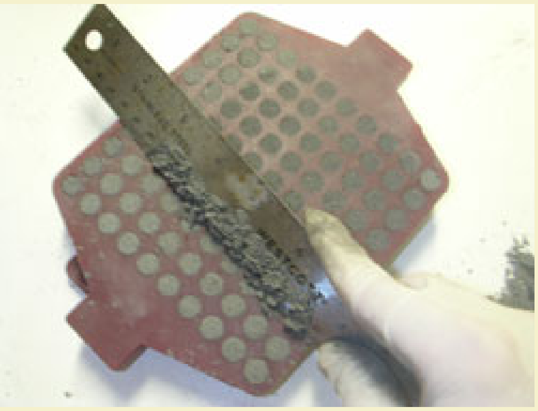

Figure 5: Shaving excess comp from bottom of plate prior to ejecting stars.

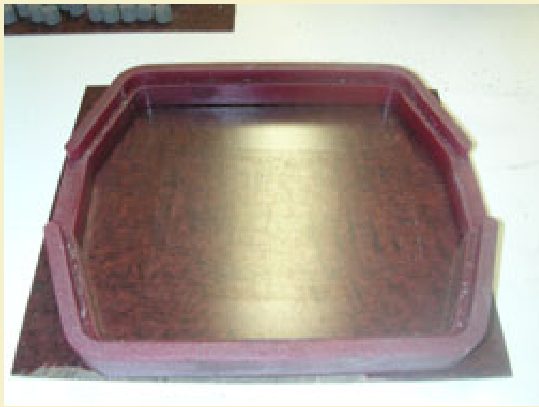

Figure 6: Standoff fixture positioned on a sheet of plastic.

The composition to be pressed must first be dampened with the appropriate binding solution. There are no hard and fast rules that apply to all compositions dictating what percentage of moisture to add. Each composition behaves differently when damp, so the amount of moisture added must be determined by practice. A good starting point is to use 10% and then increase in increments of 5% until the composition is still crumbly but will clump together if gripped in your hand. The amount of moisture will be less than if making cut stars but more than if pumping comets. A typical organic color composition might require 10% moisture, while a composition heavy in magnalium and parlon can require around 25% in some cases. If the stars are crumbly and break in half after being pumped, then you can throw them back in the bucket and add more solution. However, solution oozing out the bottom of the star plate while pressing is an indication that you added too much moisture.

Once your composition is dampened to the desired consistency, you load the plate by grabbing a handful of comp and working it into the holes as seen in Figure 2. Press with your palm while sliding the comp all over the plate. Use an excess amount and don't worry about it spilling over the sides. Once the holes are all filled, use a thin blade such as the metal ruler shown in Figure 3 to shave off the excess.

Next you will place the pin plate on top and press by hand until the holes are all aligned. Use repeated blows from a rubber mallet to consolidate the composition. It helps to do this on a solid table surface so that the pounding force is not absorbed by a flimsy table top. Do not whack as hard as if you were ramming a driver, but make sure to move the mallet around the edges to be sure all the pins are compressed equally well. Failing to compress all areas of the plate surface will result in some stars breaking in half when they are ejected.

Once the composition has been compressed, flip the plate over and level off the comp flush with the plate by scraping with the metal ruler again, as seen in Figure 5. The stars are now ready to be ejected.

Figure 6 shows a plastic ejecting frame that is part of the Skylighter star plate kit. This serves to hold the plate up off the table while the stars are being ejected. If your plate does not have one of these, you can improvise one by using to sticks of wood on both edges to hold the plate up off the table. Make sure your stand-offs are thicker than the thickness of the stars you are ejecting though, otherwise you will crush the stars against the table when they are ejected!

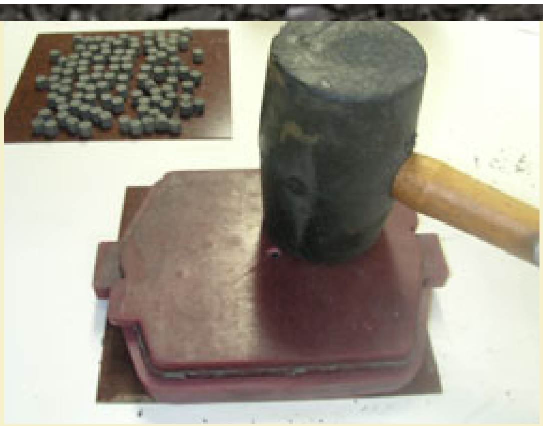

Figure 7: Ejecting stars by tapping with a rubber mallet.

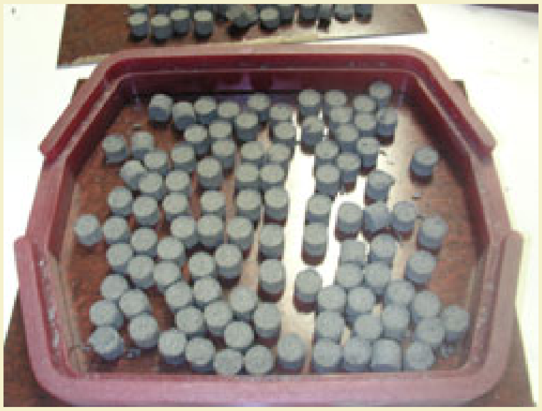

Figure 8: Finished stars ready for drying.

I prefer to eject the stars onto sheets of thin plastic so that I can easily move them around and transfer them to the drying screen. The plate is placed on the stand-off and the mallet is again used to tap the top plate. To not pound the plate to heavily or the vibrations could cause the stars to fracture if you are using a more fragile type of mix.

Figure 8 shows a completed batch of stars ready for drying. Pumped stars are really not damp enough to pick up meal dust, so they are first dried and then primed in a star roller later.

The disadvantage to this method is that it can be tricky to get all the stars to pump to the same height. This is because it is not easy to reliably press the same amount of comp into each hole when loading the plate by hand. The loading process is also slower than the second method described here. However, this method allows for a thinner star plate, thus reducing the cost of the tooling.

More...

Pumping Stars with Star Plates...

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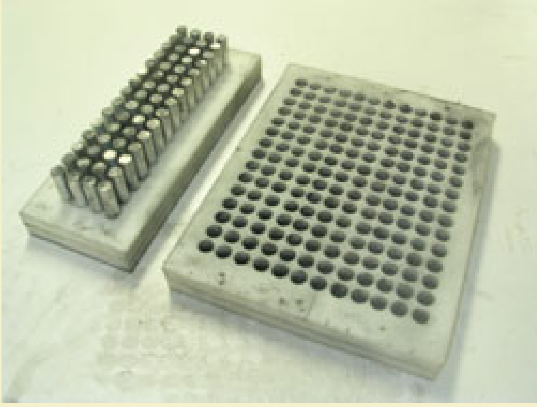

Figure 9: A thicker star plate.

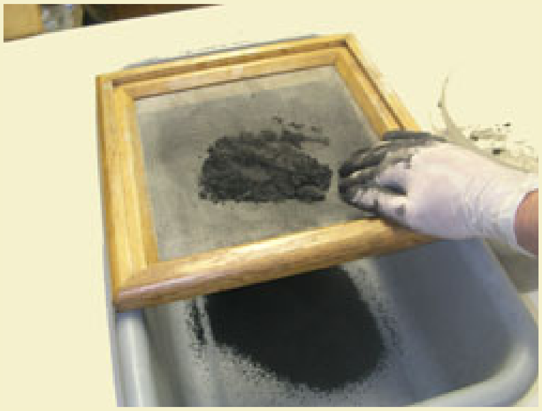

Figure 10: Granulating damp composition through a window screen.

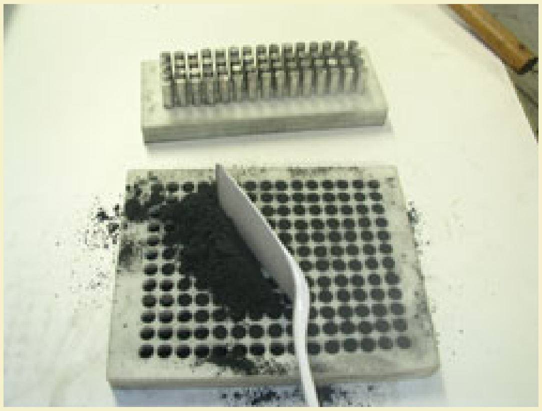

Figure 11: Filling plate holes with granulated comp.

Method 2:
This method gets around the size inconsistency problem by insuring that the same amount of composition is pressed into each plate hole. This is done by first granulating the composition, then allowing it to loosely fill each hole without any force being used when loading.

Because the granulated comp is loosely sifted into each hole, it will compress a great deal more than the solid comp pressed in by hand as previously described. This extra degree of compression, often greater than 50% of the hole length, requires a much thicker plate to be used. Figure 9 shows the thicker hole plate with the longer pin plate to match. This plate, which is 7/8" thick for pumping 3/8" stars, is almost twice as thick as the 1/2" plate used previously.

The difficulty in finding thick material to make the hole plate, be it plastic or metal, is the down side to using this method. But once you have the tooling in hand, this method is faster and produces more uniform stars than the previous method.

The composition is first dampened as described already. The dampened composition is then granulated through a window screen as shown in Figure 10. If the screen gets clogged up by the damp comp and is difficult to push through, then the composition has been over wetted.

Screening too much comp at once can sometimes cause clumping due to the weight of the screened pile compressing itself. Overly damp composition will also result in clumping, which makes it difficult for the material to flow into the plate holes. It is best to screen only enough to do one or two pressings, keeping the remainder of your comp in a closed container so that it does not lose moisture and become too dry.

The granulated composition is now poured onto the hole plate and leveled off with a straight edge until all the holes are filled to the top. This stage is much faster and requires less physical effort than method one, so the extra time spent granulating the composition is made up for with faster loading times.

At this point the process is finished out identical to the previous method. Note that the pin plate used here only fits into a third of the holes on the hole plate. This is a design used to save time and money when fabricating your own star plate such as I have done here. Since the pin plate is the most costly and time consuming component to make, creating a partial sized pin plate that fits into identical sets of holes saves a lot of time and effort while still allowing you to build a high capacity star plate. It also results in a pin plate that is easier to remove, since pin plates tend to bind as their size increases (especially pin plates made using only a drill press!).

While the pressing operation with partial pin plates requires multiple pressings (three in this case), the increased process time is not significant. I have seen this method used to produce star plates with a 400 star capacity that required four separate pressing operations per plate. A full sized pin plate of this size would be pretty much impossible to use due to binding problems, but a partial plate makes such a large star plate practical and highly efficient for large volumes.

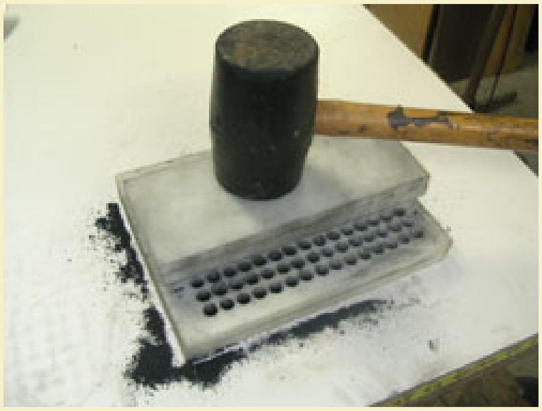

Figure 12: One of three pressings required for this plate.

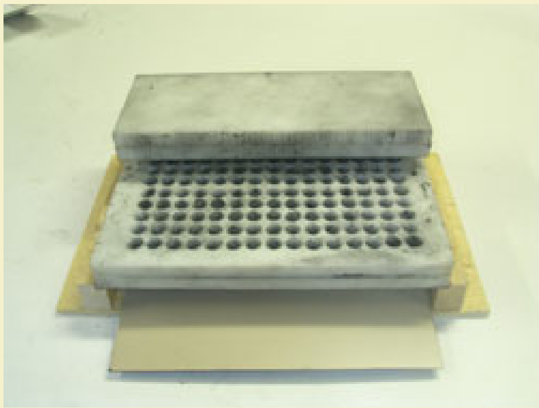

Figure 13: Ejecting the stars using a wooden holding fixture.

Figure 13 shows a wooden stand-off fixture used to hold the plate while the stars are ejected. A removable sheet of plastic is used to catch the stars as they drop form the plate. The stars will be ejected in three separate groupings due to the partial pin plate. Sometimes a few ejected stars will bounce and turn on their sides, with the potential to roll under the plate where the next group of stars will be ejected. Sliding the plastic sheet back in order to move the ejected stars a short distance away from the next pressing helps insure that you don't press the next batch on top of some stray stars from the previous batch, thus crushing some stars.

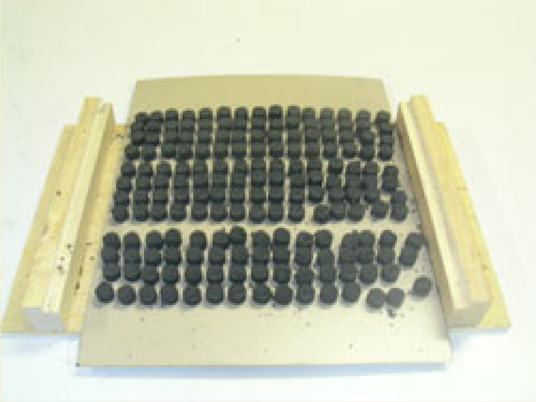

Figure 14: 180 stars ejected onto a removable sheet of plastic.

Regardless of which method you use to make plate stars, you will find that the technique is easier to learn compared with round or cut stars, and the end results are always nice looking stars. Plate stars are also ideal for converting small test batches or leftover material into useable stars, since the minimum batch size to produce plate stars is very small compared with cut stars or round stars.

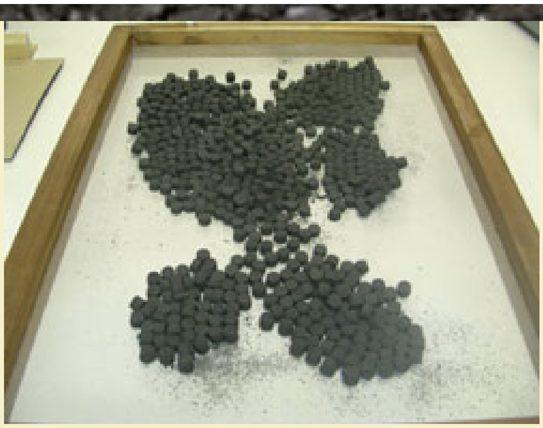

Figure 15: A screen full of pumped stars ready for drying.

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Volume 6, Issue 3

Wax Dipped Crossettes

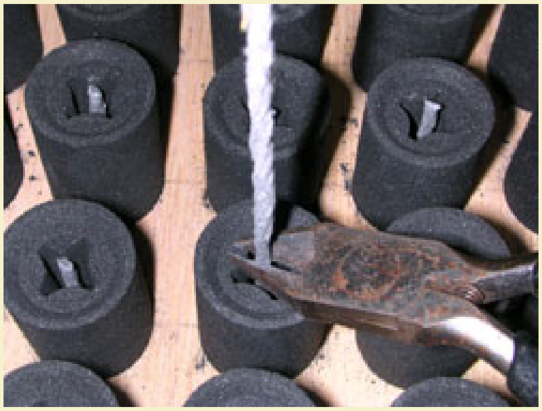

Figure 1: Inserting Chinese paper fuses into the crossette cavity ignition hole.

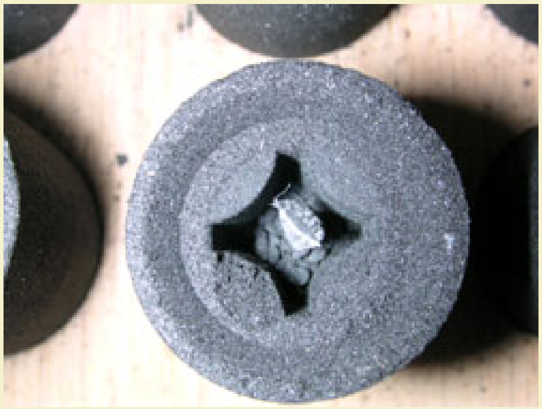

Figure 2: Crossette cavity filled half way with 2Fg.

Introduction:

Crossettes are among the more technically challenging articles to manufacture in pyrotechnics, especially in the smaller sizes. A shell that throws out a good many crossettes that all break at the same time into nice symmetrical patterns is an impressive sight that is worth the effort however, and the ability to produce such a shell will always earn you respect among your pyro peers. Such a feat displays both consistency in manufacture between hundreds of pieces, control over many variables and the patience of a saint!

Traditional crossettes are pasted in with an outer layer of thin paper, which prevents anything other than the end of the crossette from taking fire from the burst charge. This paper also adds extra confinement so that the crossette will break with more force. For more information on traditional crossette construction, click here.

The pasting of crossettes is among the more time consuming steps, and as a method of creating a fire block it is not without potential problems. A paste wrap can sometimes have wrinkles that run down the side if it is not applied perfectly flat, and these air channels allow fire to race up the side of the crossette. Paste wrap flaws and wrinkles are the most common cause of crossettes that break early, since the fire jumps ahead and reaches the burst cavity ahead of schedule.

A faster and more reliable method of fire protection is to dip the finished crossettes into a fire proof liquid that quickly dries and adheres to the surface of the crossette. This is often how commercial crossettes are manufactured in modern times, as the time savings can be considerable. There are several choices of material to dip the crossettes in, including wax, plastic, shellac and even the liquid rubber tool dip sold for coating tool handles. Wax is the cheapest, fastest drying and most readily available material, so that is what we will be using here in this article.

Crossette Construction

In order to get good performance out of a crossette that does not have a paste wrap, the crossette itself must stand on its own in terms of providing enough confinement. This means that the crossette must be very rigid with a strong seal on the end plug that covers the break cavity. If you can crush your crossettes between your fingers after drying them, then they will not work with the wax dip method. You should not be able to easily snap the crossette in half by hand or cave in the burst cavity by squeezing them between

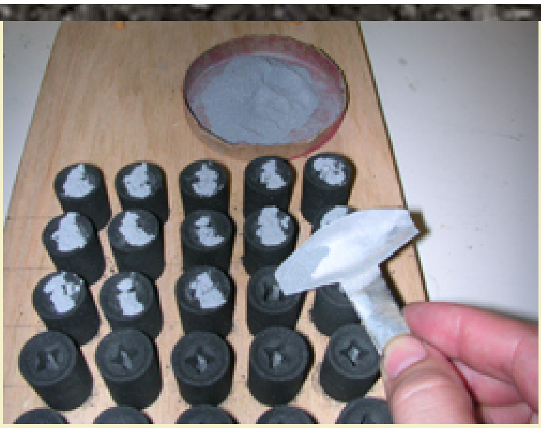

Figure 3: Filling the remainder of the crossette cavity with flash.

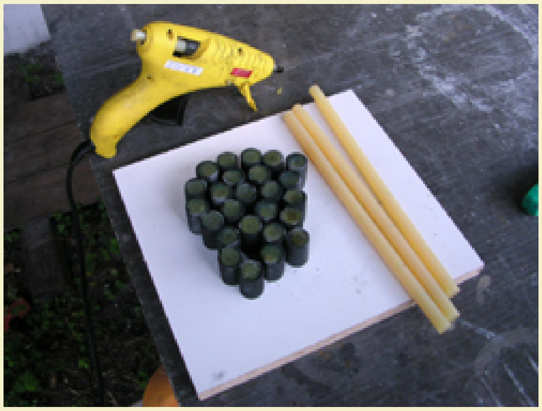

Figure 4: Using hot glue to plug the top of the crossette cavity.

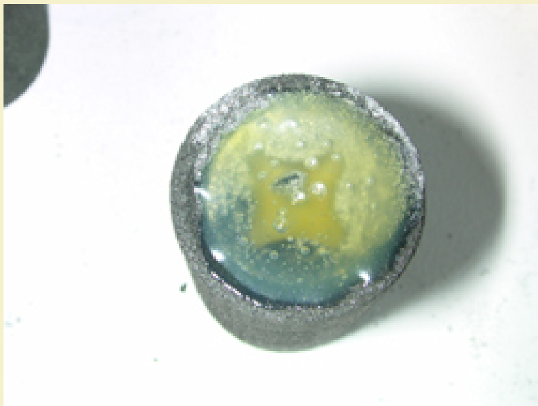

Figure 5: Close-up of hot glue plug.

your fingers. Because charcoal crossettes with high percentages of charcoal are among the weakest types, this was the type chosen to produce for this article in order to show that even the worst-case example can still be used with the wax dip method.

The primary key to making good strong crossettes is to use a solution containing gum arabic when pumping them. Simply dissolve 30 grams of gum arabic per one quart of water and use this to dampen the composition prior to pumping the crossettes. The dextrin component of the crossette formula is still added for extra binding, but relying on just the dextrin for binding the dry crossette will give inferior results. The crossettes made here are Shimizu's Tiger Tail formula using yellow pine for the charcoal, which are bound using 15% of the gum arabic solution.

The second factor to insure strong crossettes is to pump them with enough force to create a dense grain. The crossettes shown here were pumped with a 2 ton arbor press. They should not be pressed so hard that it takes a lot of force to push them out of the pressing sleeve, but they should not slide out easily either. Even properly pressed charcoal crossettes will still be fragile when they are wet, requiring great care when pulling them off the end of your rammer, but they will dry quite hard due to the gum arabic binder.

Most crossette rammers have a small pin at the tip that produces an ignition hole in the bottom of the burst cavity. The purpose of this hole is to allow fire to get into the burst cavity before the bottom of the cavity completely burns away, thus allowing some additional confinement. However, just the cavity alone is not usually enough to insure that the crossette breaks before the cavity bottom burns away. A more reliable method is to insert a small diameter fuse into this cavity so that rapid fire transfer is insured. Some people use thermolite or small diameter visco for this fuse, but I find that the best results are obtained by making a fast burning Chinese type of paper fuse using fine-grained corning dust as the fuse powder. The method of rolling this simple type of fuse can be found here. Figure 1 shows how segments are trimmed from a longer length of fuse to fit each crossette.

The next factor in producing wax dipped crossettes is the break charge. Breaking a dipped crossette is a little like breaking a plastic shell compared with a paper shell-- meaning that a stronger break charge must be used. For the 3/4" crossettes shown here, which were made with Rich Wolter's crossette pump, a burst charge of 50% 2Fg black powder grains and 50% 70-30 flash made with American dark aluminum is used. The black powder grains are an important element that increases ignitability, eliminates the "jetting" problem, regulates burst strength and eliminates the white flash that a flash-only break charge would produce. Anyone who has ever seen charcoal crossettes break with a bright white flash of light knows how annoying this defect is, so don't identify yourself as a crossette rookie by making flashing charcoal crossettes.

For those that corn your own home-made black powder, getting the small 2Fa grains is no problem. If you don't make your own grain powder, then you could try granulating some 20% dampened meal through a window screen and using those grains as a substitute.

Figure 2 shows the burst cavity half filled with the small grains of home-made 2Fg black powder. A tool for loading the BP into many crossettes at once is described here.

The final trick to producing a strong crossette is to eliminate the traditional end disk altogether and just fill the top of each burst cavity with a solid plug of hot glue. Hot glue provides a superior plug compared with the traditional method of gluing a cardboard disk over top of the hole, and is also faster. Not all hot glue will work for this application though, so it is important to get the right kind. There is a yellow colored type of glue used for sealing cardboard boxes that bonds very well to almost anything and dries rapidly. The rapid dry time helps reduce the problem of air bubbles forming in the glue as the heated air in the burst cavity tries to escape. Slower drying glue will allow these bubbles to form and potentially breach the plugs integrity. Two varieties of fast-set packing glue can be found at PyroSupplies which will work well for crossette end plugs.

The hot glue plug not only adheres to the crossette better than a traditional end disk, it also flows into the top of the burst cavity and provides a bulkhead to help withstand crushing forces from the outside-- something an end disk can't do. Figure 5 shows a completed crossette with the glue plug. If you want to see just how strong these plugs grip the crossette, just try and pry that puppy off! Sometimes the paper fuse may stick up out of the glue, in which case you will need to add another drop on top of it to prevent it from igniting and spoiling your crossette. Care should also be taken to make sure there are no gaps around the edges of the plug that could allow fire to sneak in under the glue.

You may have anxiety about shooting hot glue directly on top of flash, which is not really as risky as you would think. Flash actually has a pretty high ignition point and is not easy to set off even when you are trying to ignite it sometimes! However, the charcoal in your crossette and the paper of the fuse inside the break charge have a lower ignition point so a low temperature glue gun should be used. A low temperature gun will also help the plugs dry faster and reduce the air bubble problem as well. The ignition point of paper is around 450 deg. F, so you want to stay well below that. The filling operation should also be done outdoors, away from any other pyrotechnic materials, while wearing shaded UV eye protection just to be safe.

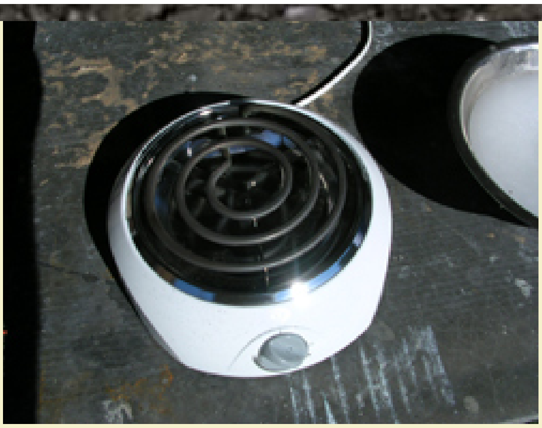
Figure 6: A portable mini-stove for heating the wax.

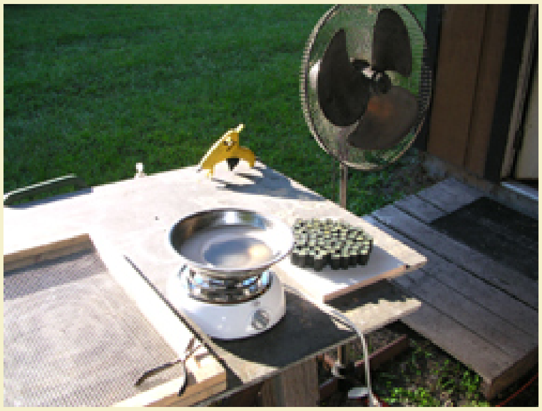
Figure 7: Dipping station includes wax pot, fan and screen.

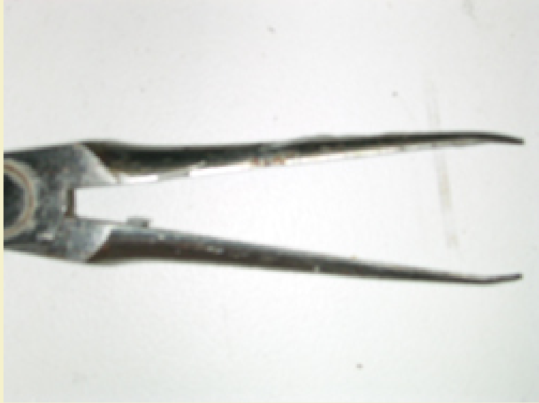
Figure 8: Thin needle nose pliers bent at the tip for holding crossettes while dipping.

Dipping the Crossette

The trick to making wax dipped crossettes is in making the crossette themselves. The dipping is the easy part! Paraffin can be found sold in large blocks in many craft stores for the purpose of making candles. This can be heated in a stainless bowl on top of a portable mini-stove as seen in Figure 6. The temperature of the heated wax is a critical factor that will control both the thickness of your wax coating as well as how far into the crossette the wax will penetrate. If the wax is too hot, it will absorb completely into charcoal crossettes rather than build up on the outside, which will also ruin the spark tail. The desired temperature is around 150 degrees F, which is pretty close to the melting point of the wax. Higher temperatures will result in thinner coatings, while lower temperatures will give thicker coatings. The usable temperature range is pretty narrow however, and fluctuations as small as 5 degrees during the dipping process can change the thickness of your coatings.

Figure 7 shows an outdoor dipping station, which consists of the wax bowl, a fan, a drying screen and some pliers for gripping the tip of the crossettes. Since the wax is not hot enough to burn your fingers, you could try gripping the tips by hand to dip them, but the pliers make it easier to control how deep you dip them. The pliers shown in Figure 8 is a small needle nose type where I bent the tips at a slight angle so that they can grip the crossettes better. After dipping hundreds of crossettes, I have yet to accidentally drop one into the wax (knock on wood). Care must be taken not to let any wax get on the ignition surface of the crossette, since that would prevent the prime from sticking and potentially render it useless. I like to dip them to within 1/8" of the top of the crossette, as seen in Figure 9. Also be sure to always dip them with the glue-plug end down!

If the wax is just above the melting point, you can get away with one coating, otherwise you will need two coats. When doing more than one coat, the fan helps to rapidly dry the crossette and blow off any excess drops that form on the bottom after dipping. Since crossettes are often stacked in a shell, you don't want any wax buildup on the bottom that can be formed when dripping wax hardens.

The drying screen helps keep the crossettes from getting stuck to anything while they dry. Be sure to inspect the bottom of each crossette after dipping to insure that no air gaps or holes exist in the wax coating. The walls will always coat without problems, but sometimes the bottoms will have missed spots. For color crossettes this is not much of an issue, since color compositions tend to not take fire without a prime anyway, but charcoal crossettes are very sensitive to ignition, especially around the edges.

Figure 12 shows the finished coating on two crossettes. The one on the left has been correctly coated and the one on the right may not have enough wax to protect against accidental ignition. The most ignition prone area is the edges around the glue plug, so the wax must be thick enough to completely cover this edge.

The wax will not effect the visible performance of the crossettes at all, so long as it was properly applied and did not absorb excessively into the composition. About the only side-effect of the wax I have noticed is that some sparks will burn longer than usual on charcoal crossettes and potentially make it all the way back down to the ground. This is not something that you would see at a distance, but it could be a fire hazard to consider when shooting in a dry area.

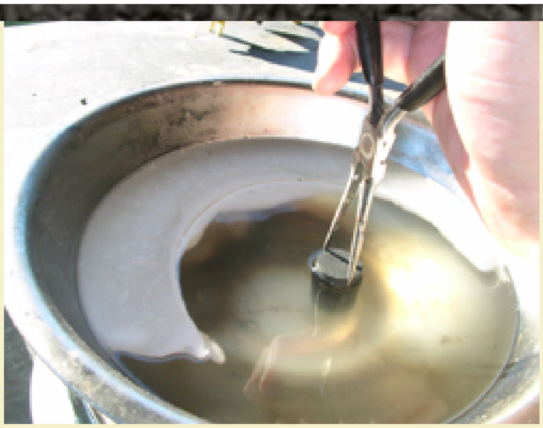
Figure 9: Dipping a crossette into the wax.

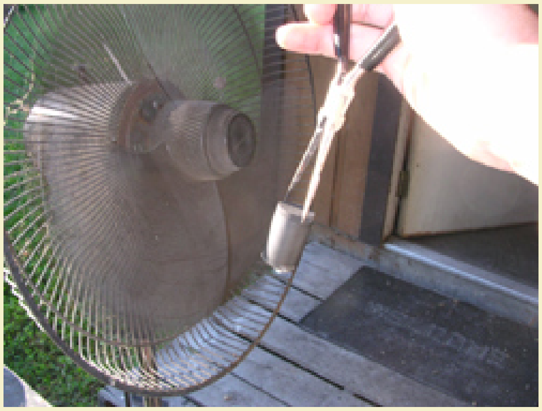
Figure 10: Speed drying the wax in front of a fan.

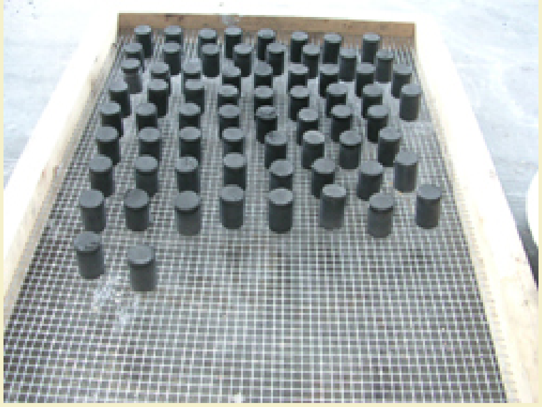
Figure 11: Screen filled with dipped crossettes.

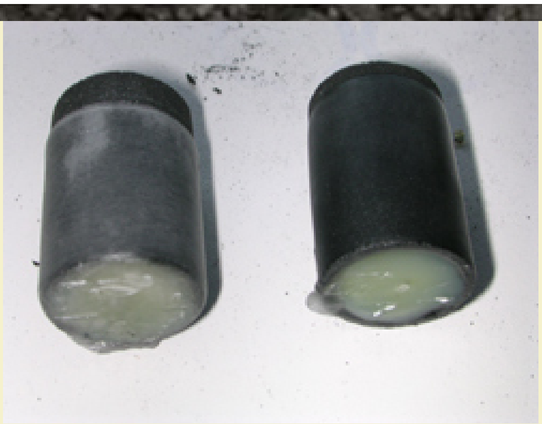

Figure 12: The desired thick coating at left compared with a thinner one that may not protect against accidental side ignition as well.

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Volume 2, Issue 12

Tool Tip...

Page 1

Low Cost 4" Comet Pumps

Introduction:
This project was designed around two guiding principles: 1) bigger is better and 2) pyro hobbyists have no money. Many of you have probably been wanting to make large comets, but have been denied this endeavor due to a lack of affordable tooling or the ability to make the tooling yourself. The tool shown here can be made from parts readily available in most hardware stores, with a price tag below $20 for all materials. The method of comet pump making shown here can be adjusted for any size comet you want, be they hollow core or solid. All without the need for large, expensive chunks of metal, machine tools or wood lathes.

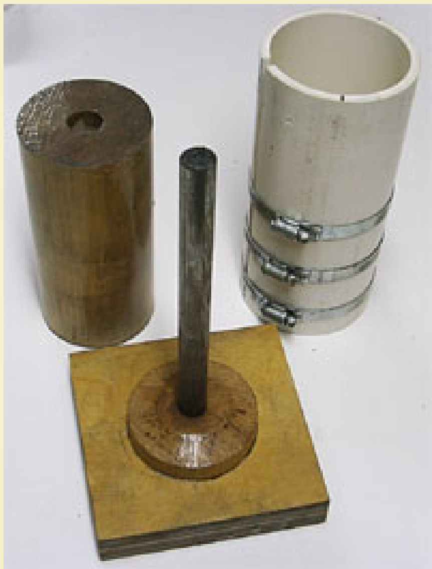

Figure 1: A wooden comet pump turned on a lathe.

Figure 1 shows a wooden 4" comet pump that I turned on a lathe. However, I figured that most people don't have a wood lathe and if they did, they wouldn't need me to tell them how to make something as simple as a 3-1/2" diameter cylinder with a hole through the middle! The sleeve shown in Figure one is a segment of 4" PVC that has been reduced in diameter so that the I.D. measures 3-1/2". The procedure for doing this is shown below.

Those that do have a wood lathe have the advantage of being able to turn a custom profile such as a sphereical spindle base, which is necessary when making large comets that can be attached to ball shells. The comet pump described in this article makes comets with flat surfaces on both ends, which works fine for stand alone comets and comets that can be attached to canister shells.

Making the Sleeve:
The pump shown here is made using two segments of PVC, as shown in Figure 2. The idea of using PVC sleeves to pump comets is definitely not new, but it presents a problem when the standard diameters of available PVC do not match the comet diameter that you need.

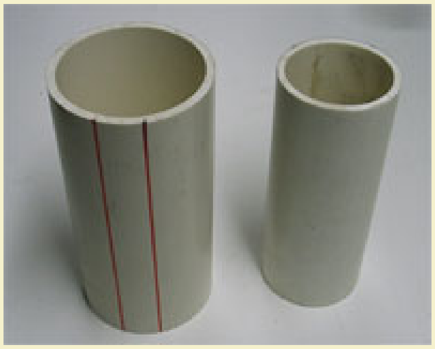

Figure 2: 4" PVC outer sleeve and 3" PVC inner piston.

Since there is no PVC with a 3-1/2" inside diameter, it becomes necessary to shrink down a segment of 4" pipe. Start with a 9" long segment of 4" PVC that has a 1/4" wall thickness. Mark two points on the outside edge of one end that are 1-3/8" apart. This is the segment of pipe that you will need to remove. You will need to mark guide lines down the side of the pipe as shown in Figure 2. This is easily done by laying the pipe on it's side next to a thick piece of wood that runs the length of the pipe, using the wood as a guide when drawing the lines.

The tricky part is making the two cuts to remove the unwanted segment of pipe. The easiest tool to use for this is a thin kerf Japanese hand saw, as seen in Figure 3. A bench vise is really handy for holding the pipe while you are sawing. As you make the first cut, the pipe will want to close in and bind

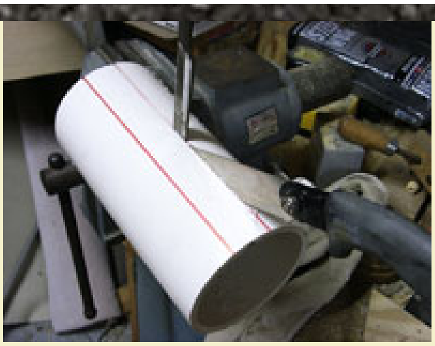

Figure 3: Reducing the diameter of the 4" pipe to 3-1/2" I.D.

the saw. About halfway through the cut it becomes necessary to wedge a chisel into the gap to hold it open while you cut. Making the second cut is easier and should not require this step.

Once you have cut out the thin strip, clean up the edges with sand paper or a deburring tool. Next you will want to use three pipe clamps to pull the pipe in and close the gap as much as possible. Make sure that your 3" I.D. piston pipe still fits easily inside the sleeve when the gap is closed. The piston pipe is also a 9" long segment of 3" PVC which also has a 1/4" wall thickness, making the O.D. equal to 3-1/2".

Once the sleeve gap is pulled in as close as you can get it, and it looks like the piston will fit inside with no problems, place the sleeve in an oven set to 250 deg. for about 15 minutes. This will soften the plastic and cause the pipe to maintain it's new diameter once the pipe clamps are removed. Allow the pipe to cool fully before working with it, as it will be very pliable coming out of the oven.

Figure 5 shows a perfect fit of the reduced 4" pipe with the 3-1/2" O.D. piston pipe inside of it. If there is a lot of space around the inner pipe, you can always slice off another thin strip from the pipe with your saw. However, if the sleeve is now too small to allow the piston to fit inside, you will have to start over using a narrower gap such as 1-1/4" next time.

More...

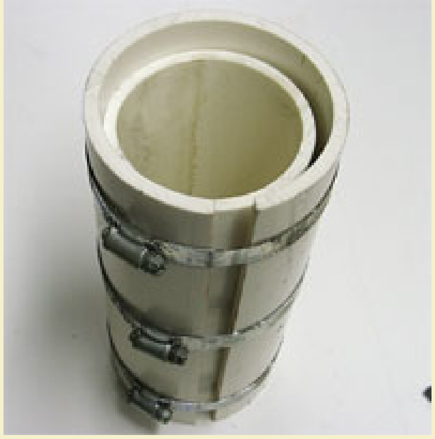

Figure 4: Pipe clamps used to close the gap prior to heating in oven.

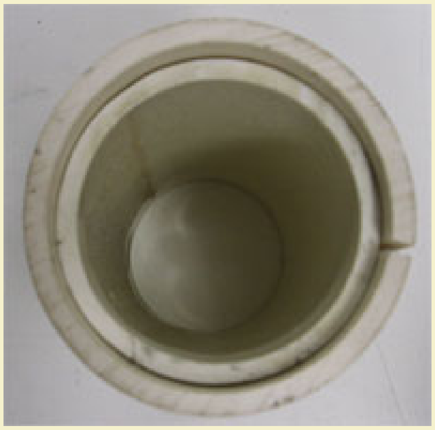

Figure 5: After heating the sleeve should fit snugly over the piston pipe.

4" Comet Pump

Page 2

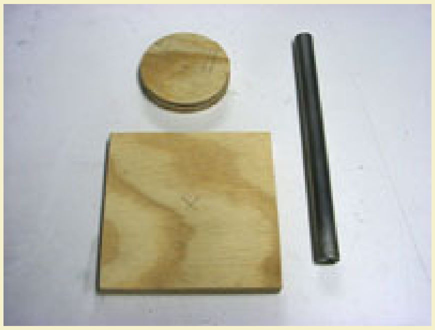
Figure 6: Plywood base, 3-1/2" dia. disk and the 3/4" aluminum rod.

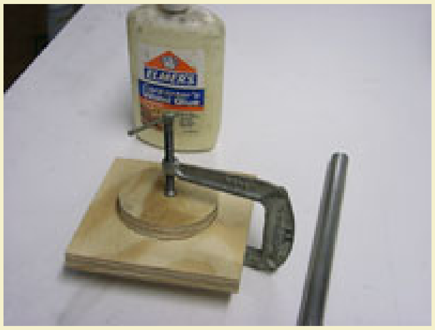
Figure 7: Attaching disk to base using wood glue and C clamp.

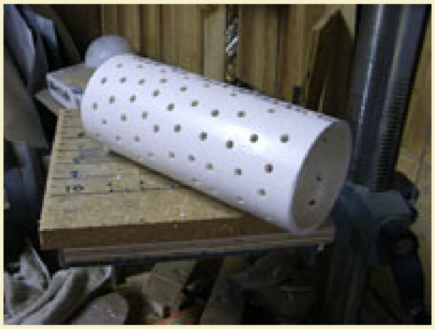
Figure 8: Perforating the piston pipe with 1/4" holes.

Building the Base:
Since this comet pump is for producing hollow core comets, it is necessary to use a base similar to a rocket spindle. The base is nothing more than a block of wood that holds a 3/4" metal which is cut to 10" long. I prefer a solid piece of aluminum bar stock, which can be found in most scrap yards for only a few dollars. Hollow tubing can be used, but the top end must be plugged to keep powder from falling into it while loading the sleeve. This is easily done by stuffing a wad of paper into the end and then filling over top of it with hot glue.

The base is made from a 6" square piece of 3/4" thick plywood and a 3-1/2" diameter disk also made from 3/4" plywood. Plywood is preferred over solid wood because it will not split under pressure.

Use a compass when marking the circle to cut for making the disk so that you will know the exact center point. You will drill a hole here later, so mark it with an X. The disk can easily be cut on a band saw or router table. If you have neither of these you can use a saber saw, saws all or similar hand held tool to try and cut the circle. Or you can just find a friend with wood tools and have him make it.

The wooden disk is simply glued to the middle of the square base using wood glue and a C clamp, as seen in Figure 7.

Once the glue is dry, you will need to drill a 3/4" hole about 1" deep into the base using a spade bit. Use of a drill press is the best way to insure that the hole is exactly perpendicular. Drill presses come in handy for all sorts of pyro applications, so if you've been thinking about buying one then now you have one more reason!

The spindle rod should fit snugly into this hole, but there is no need to permanently secure it in place. Just press fitting the rod in place allows you the ability to interchange it with shorter rods for making cavity comets, which are comets where the core does not go all the way through the comet.

Making the Rammer:
While the glue is drying on your base, take your 3" PVC piston pipe and drill a bunch of 1/4" holes through the sides as shown in Figure 8. The purpose of these holes is to allow the plaster that will be poured inside to have a firm grip on the walls, insuring that there is no chance the core could ever break loose from the outer pipe. Do not worry about precision spacing with the holes, just randomly perforate the pipe with them.

Once your base is completed, you will use it for the mold when pouring the rammer. You will need to prepare the spindle rod by rolling two turns of kraft around it to increase it's diameter slightly. Be sure to leave 1" exposed from the end so that you can insert it back into the base. Next you will need to roll another two turns of wax paper around the kraft paper so that the spindle and paper can be removed from the mold when it dries. Since nothing sticks to wax paper, you will have to secure the two turns in place using heat to melt the wax together. I do this by heating a chisel with a blowtorch and then rubbing the hot metal over the seam to seal it down.

Place a piece of wax paper over the base and then press the spindle back into the hole through the wax paper. You will also need to roll a few turns of kraft around your perforated rammer pipe in order to minimize liquid plaster from running down the sides. Figure 9 shows the base and rammer prepared for pouring.

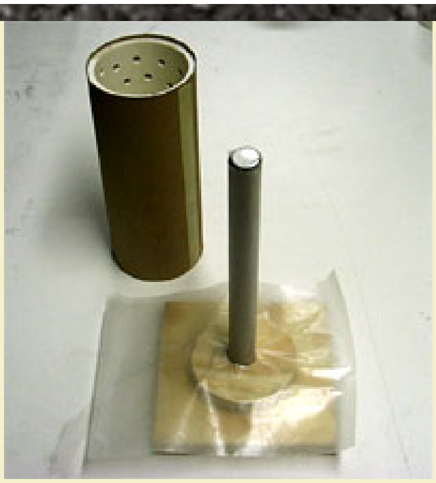

Figure 9: Base and rod are protected with wax paper.

First slide the sleeve onto the base over top of the wax paper. Next you will need to wedge the rammer into place. The two turns of kraft will increase the diameter so that it no longer easily fits into the sleeve, so you will need to use a screwdriver to pry open the sleeve until you can push it down into place. Figure 10 shows all components ready for the pour. Be sure that the spindle sticks up higher than the rammer and sleeve, otherwise it will get buried under plaster.

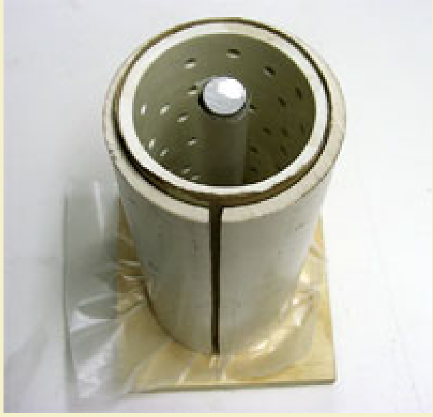

Figure 10: All pieces in place and ready for pouring the core.

More...

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4" Comet Pump

Page 3

Pouring the Plaster:
While there are a couple of fillers that could be used to pour this mold, the easiest one to work with by far is Durham's Rock Hard Water Putty, shown in Figure 11. This yellow powder is simply mixed with water like plaster of Paris, but unlike plaster of Paris it dries so hard that it is difficult to even sand it. This stuff is so strong I have even heard of people using it to plug the bottoms of mortars! It dries fast and is easy to wipe from places where it is not supposed to be.

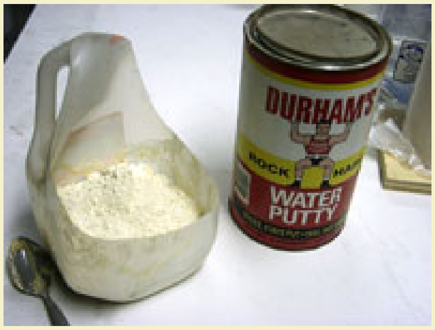

Figure 11: Mixing Durham's Rock Hard Putty in a cutoff milk jug.

Another substance that can be used, and will also never crack under pressure, is fiberglass resin diluted heavily with sand. This is a bigger pain to work with and also requires more skill to properly prepare. It must be diluted at least 50% by volume with sand, which conserves resin and also helps prevent excessive heating as the resin dries. The mess, fumes and difficulty of cleanup makes this method unattractive.

You will need the 4 lb can of Durham's to make enough to fill this mold. I prefer to mix this putty in a modified milk jug, shown in Figure 11. The thin, flexible jug allows you to easily crack off the dried leftovers and remix a new batch between applications. It will take two batches of the size shown in Figure 11 to fill the mold. If you work fast enough you can mix the second batch without cleaning the jug from the first batch.

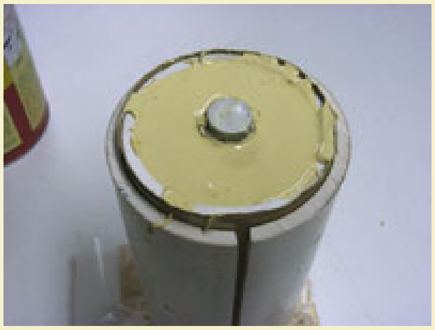

Figure 12: Piston is filled to the top with water putty.

Simply add water and stir with a spoon until a creamy consistency is reached. It should not be thin enough to be poured, rather you should have to scoop it into the mold. You don't want it too thick either or it will not settle into the holes and air may get trapped between lumps.

Fill all the way to the top of the pipe, then clean off the end of the spindle so that it is not buried in putty. Figure 12 shows the finished pour.

After about 20 minutes the putty will reach a semi-dried state where it is still soft enough to scrape but solid enough not to deform or run. At this point you want to remove the sleeve and pull the rammer off the spindle. Unwrap the kraft wrapper and use a thin metal blade to shave off any putty that squirted out the holes. Also clean up the ends of the rammer as much as possible, because it is much easier to trim off the putty now than when it dries. The paper tube left inside the rammer should slide out, leaving only the wax paper. Try and pull out as much of the wax paper as you can. If some wax paper gets stuck inside the cavity wall then don't worry about it.

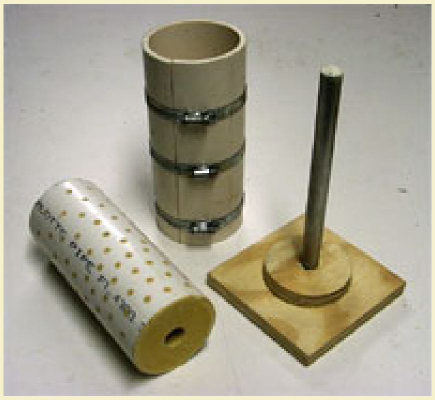

Figure 13: Complete 4" hollow core comet pump for under $20!

Figure 13 shows the completed comet pump set. The exposed wood on the base should be protected with varnish, krylon or other sealer so that the pump can be hosed off after use. It is a good idea to seal the exposed plaster on both ends as well, since it will absorb water.

can also be had in economical 25, 50, and 100-lb. drums.
Rocky sez . . .
Works great for making 4" comet pumps!
HELPFUL SUGGESTIONS

Listen to what Rocky sez!

The end of the rammer that is very flat should be the end that gets pressed from above when pressing comets. Ideally both sides of the rammer will be flush and flat so that you don't have to worry about which side to press against.

Note that both top and bottom of this pump must be sandwiched between at least 5" square metal plates, which will distribute the pressure evenly so that the pump does not get damaged. For more information on how to use this pump, see the 4" comet article in this month's issue.

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Volume 1, Issue 2

Tool Tip...

Anvil Cutter Length Gauge

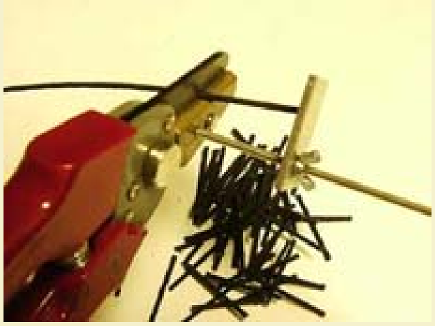
Figure 1: Cutting equal length fuses.

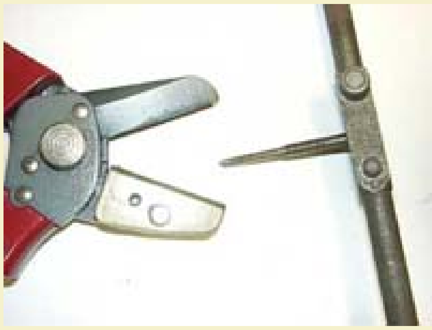
Figure 2: Hole is drilled and tapped.

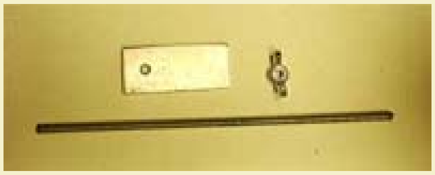
Figure 3: Stop plate, lock nut and threaded rod.

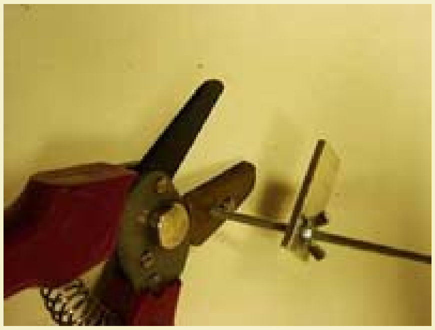
Figure 4: Assembled cutting jig is ready to go.

Measure Once, Cut Forever:
Lets face it, making fireworks has its monotonous moments. Cutting a thousand pieces of fuse to an equal length is one of those moments, but it doesn't have to be as painful or time consuming as you think. The tool modification presented here uses the age-old concept of a stop gauge to eliminate the repetitive task of hand measuring an equal distance over and over. The desired length is measured once, from the cutting blade to an adjustable stop plate, then the stop plate is locked into position using a wing nut. The operator can then cut as many pieces as needed without ever having to measure them. The piece being cut is simply inserted until it hits the plate, then cut. Multiple pieces can even be cut at the same time if a thin material such as black match is being cut.

The cutters used here are anvil type cutters purchased from the garden department of Home Depot. Anvil cutters are perhaps the safest and most popular tool used for cutting active materials such as quickmatch, blackmatch, time fuse and visco. While scissor type cutting tools use a shearing action that can trap powder between the blades and subject it to a high degree of friction, the anvil type cutters use a pinching action against a hard plate that separates the material being cut with a minimal amount of friction. It is for this reason that anvil cutters are the tool of choice when cutting fuse.

Since you may not always want the stop plate jig hanging off your cutters, it is designed to easily unscrew by hand. A small threaded hole in the bottom jaw of the cutter receives a threaded rod which in turn holds the stop plate. One nice feature of the anvil cutters is the thick aluminum plate on the bottom jaw, which makes an ideal material to drill and tap. The size of the threaded rod is not important, but it is probably a good idea to keep it around 1/8" diameter so it isn't too heavy and has small enough threads so that it takes at least two turns to secure it into the cutter plate. I used a 6-32 threaded rod for the one pictured. You will also need a tap and wing nut that match the threaded rod you use.

The first step is to fabricate the stop plate, which is made by using a hack saw to cut a 1/2" piece off of some 1-1/2" by 1/8" thick aluminum flat stock (available in most hardware stores). A threaded hole will also be tapped near the bottom of this plate, so use the appropriate bit matched for your tap size to drill the pilot hole. While you have the drill going, go ahead and drill an identical hole near the back of the anvil cutter bottom plate as shown in Figure 2. Be careful not to drill all the way through the anvil cutter jaw, but try to go at least 3/16" deep.

Now a hand tap is used to thread each of the holes you just drilled. When tapping the anvil cutter, be careful not to force the tap too hard once it gets near the end, as you could bottom it out and strip the threads out of the hole.

If this happens, just make another hole and try again.

Next cut a piece from your threaded rod that is about 5" long. You should now have a collection of parts that looks like Figure 3. There should be one clean end of the threaded rod that will thread into the cutters. From this end, thread the wing nut backwards onto the rod, then thread the stop plate on till it hits the wing nut. Spin this whole assembly into the hole you made in the anvil cutter and you are done!

To use the plate, simply back the wing nut off and spin the stop plate until the desired distance between the cut line on the anvil and the stop plate has been measured. Tighten the wing nut against the stop plate to hold it in position and you are ready to go. The length of the stop plate can allow you to cut several pieces of match at the same time, drastically reducing the time required for this repetitive task.

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Tool Tip...

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Build Your Own Ball Mill

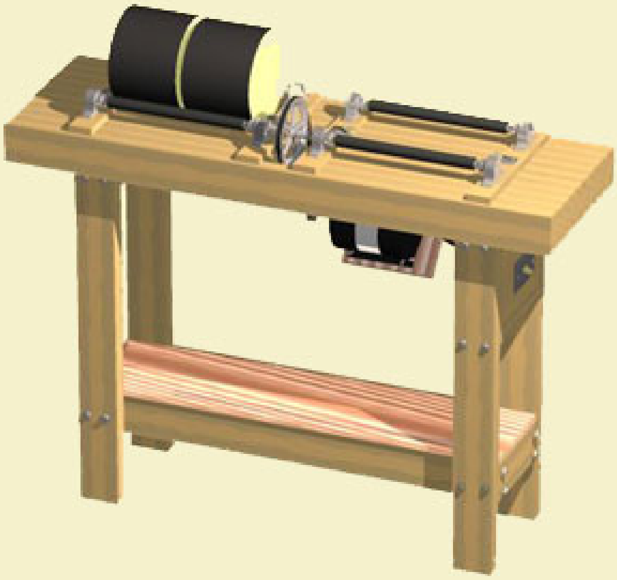

Figure 1: A sturdy ball mill that will last for years.

Materials:

- (8) 8ft 2x4s
- (1) 9" x 37" x 1/2" plywood
- (2) 9" x 5" x 1/2" plywood
- (1) 12" x 9-1/2" x 1/2" plywood
- (4) 1-1/2" x 12" x 3/4" wood
- (32) 1/4" x 3" long lag screws
- (32) 1/4" washers
- (2) 4" hinges
- (8) 5/8" base mount bearings
- (8) 5/8" shaft collars
- (1) 5/8" dia. x 36" long steel rod
- (2) 5/8" dia. x 16-1/2" long steel rod
- (4) 13" long 5/8" rubber heater hose
- (1) 6" dia. pulley
- (1) 2" dia. pulley
- (1) 31" long drive belt (4L310)
- (1) 1145 RPM, 1/2 HP AC motor
- (1) AC switch w/face plate
- (1) 6 ft. power cord

Unmeasured:

1" wood screws, wood glue

Introduction:

One of the first tools any serious pyrotechnic hobbyist will need to obtain is a good ball mill. Good quality meal powder is so essential to many aspects of fireworks making that you will not be able to do much without it. While commercial Meal D can be purchased for this purpose, the quantities you will be needing combined with the difficulties and costs of purchasing commercial powder makes milling your own far more attractive.

While small rock tumblers are often used by hobbyists for milling powder, a much more rugged mill with higher capacity can be built for about the same price or less. The mill shown in Figure 1 is a very solid, vibration resistant design with a simple gravity tensioned pulley drive system. A 13" long set of rollers on each side of the drive wheel can run two standard 10" long Sponen jars at once, or even up to four 8" diameter x 6" long "pancake" jars for potentially milling up to seven pounds of BP at a time.

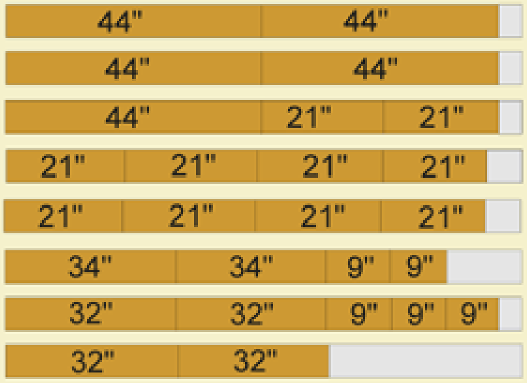

Figure 2: Cutsheet for the eight 2x4s.

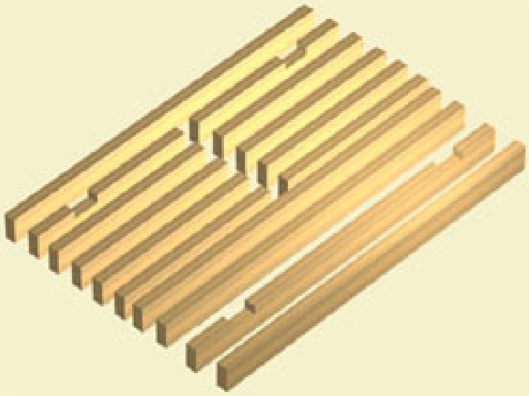

Figure 3: The 2x4s cut to size and positioned for gluing.

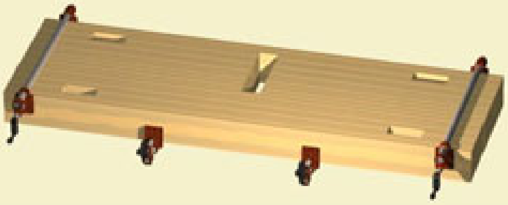

Figure 4: Using bar clamps to compress the boards together while drying.

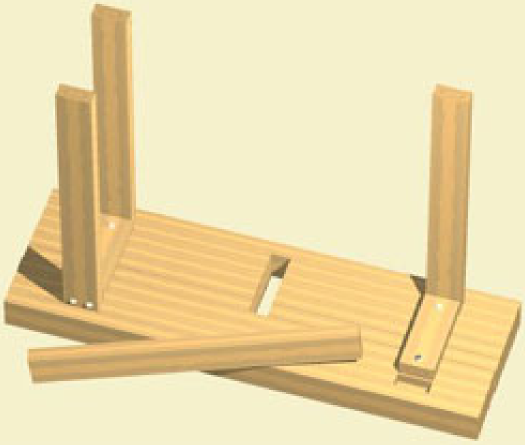

Figure 5: Assembling the table legs.

The bench for mounting the hardware is built mainly from 2x4s, which greatly reduces the amount of power tools and wood working skills required to build this mill. About 90% of the cut work can be done with a hand held circular saw for cutting 2x4s to size. The butcher-block style work surface is ideal for solidly mounting your hardware and absorbing vibration and sound as compared with plywood models.

Begin by cutting all the 2x4s as directed by the cut sheet in Figure 2. All the 44" and 21" boards will be laminated to form the table top, as seen in Figure 3. The notches shown one board in from each side are optional and make assembly a little easier. These are cut 3.5" from the ends of the boards and measure 3.5" wide by 1.5" deep. The end of a 2x4 should fit easily into the slots, since these are where the table legs will fit into. Notches of this type are easy to make by cutting many parallel cuts using your circular saw set to a depth of 1.5 inches, with the cuts being roughly 1/2" apart. A chisel is then used to knock out all the slices of wood, leaving you with a nice notch.

Because a flat surface makes powder spills easier to clean up, you may not want the big gaps between the 2x4s on the top surface. These are caused by the rounded edges that 2x4s have. The easiest way to fix this problem is to laminate a sheet of Formica over the top after the table has been glued together, then use a router to trim out the Formica around the center slot. Otherwise you can use a table saw to shave 1/2" from the top edge of each board prior to assembly. After assembly you will still need to smooth it out with a power sander to remove all uneven edges and saw marks.

Wood glue is applied liberally between each piece of wood and then they are all clamped together using 4 or more bar clamps as shown in Figure 4. Be sure the boards are all resting flat on the bars to prevent an uneven table surface. Make sure the slot at the center is aligned good, since you can sand the ends of the finished table but sanding inside the slot would be very difficult.

After 24 hours of dry time, the clamps are removed and the 32" legs are assembled as shown in Figure 5. Two 9" cross members are what actually get bolted to the table, while the legs fit into the notched holes and are then bolted to the cross members. It is best to fasten one screw into each leg first, then use a square to make sure the legs are perpendicular before drilling the pilot holes for the second screw.

Figure 6 shows the pre-assembly of the lower shelf, which gives you a place to store your mill jars as well as ties the table legs together for strength. This is a simple frame made from the 9" and 34" 2x4s, then covered with the 9 x 37 piece of 1/2" plywood using 1" wood screws to hold it down.

It is best to turn the table over upright to sit on it's legs before attaching the shelf. Make sure that all four legs will be able to sit square on the floor before attaching the shelf. The shelf is attached about 6" above the floor, which is easiest done by clamping some blocks to the inside of the legs for the shelf to sit on while drilling pilot holes and ratcheting in the lag screws. The temporary blocks are

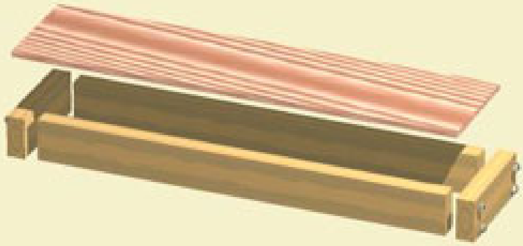

Figure 6: Making the leg support storage shelf.

then removed once the shelf is secured.

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Build Your Own Ball Mill...

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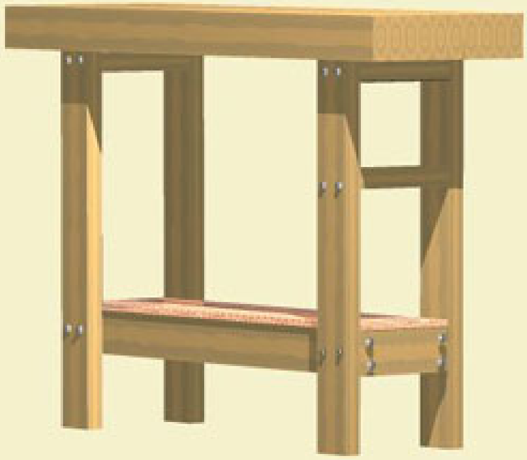

Figure 7: Table with legs framed out for switch box.

Figure 7 shows the completed table with an extra 9" cross member located 5" down from the top on one side. This frame will hold the switch box and wiring.

Next you will assemble the rollers and other components that fasten to the top of the table. The mounting bearings can add up in price quickly, as even cheaper ones with stamped housings can cost around $10 apiece. I opted to make my own by mounting $3 ball bearings into wood blocks to save money. You can save money on the shaft collars by using the strain relief collars used for electrical conduit. These often come with a coupling that screws into an outlet box which must be cut off with a hacksaw to get the collar with the set screw that fits over your 5/8" shaft. With a surplus motor, this mill can actually be built for under $100 using these cost cutting methods.

Be careful when buying your 5/8" dia. bar stock from home supply hardware stores. The rods sold there are often oversized or bent. Bring your bearings with you to the store and make sure they fit over the rods first. Also roll the rod on the floor and sight down it while spinning it to make sure it isn't bent. Sometimes you have to search through the entire bin just to find the two rods you need!

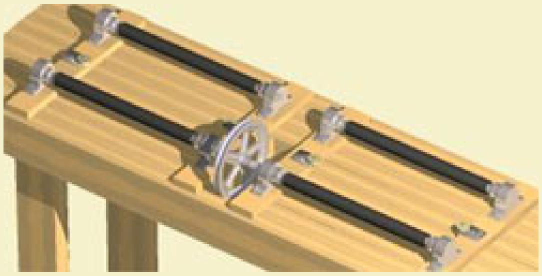

Figure 8: Working surface details.

The two 16-1/2" long roller bars are assembled by first slipping a 13" piece of heater hose over the shaft. This hose will fit very tightly, so the trick is to get it started and then push down on the end of the hose so that it compresses to make the inner diameter wider.

The 36" long drive shaft is built by first slipping a 13" piece of heater hose on one end. Then you will need to stack components onto the shaft above this hose in the following order: shaft collar, left hand bearing, 6" pulley wheel, right hand bearing, collar and finally the other 13" heater hose. Getting things out of order may cause you to have to remove the heater hose after it is already on the shaft, which is not fun! If you do have to remove the hose, find a piece of tubing that fits over the shaft and push the hose off using the tubing. Trying to pull the hose off will not work, as this stretches the hose and makes it fit tighter the harder you pull!

Fasten your pillow block bearings with the rollers installed onto slats of wood screwed to the surface of the bench, as seen in Figure 8. Fasten the drive shaft first, making sure that the pulley wheel has clearance on both sides of the slot hole. NOTE: Make sure you slip the drive belt over the 6" pulley before fastening the bearings down, otherwise you will have to take them up again to put the belt in place! Locate the idle rollers parallel to the drive shaft and about 5-1/2" between center points of the rollers.

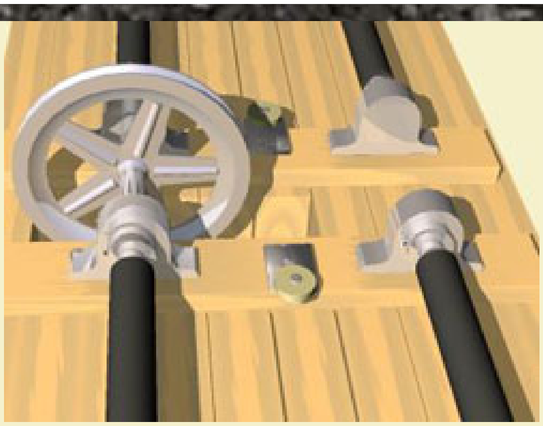

Figure 9: Note use of rollers to prevent jars from traveling off the rollers.

Figure 9 shows a close-up of the bearing assemblies and a centered idler wheel that is used to keep the milling jars from traveling off the rubber rollers and rubbing against the bearings during operation. These wheels are a type of door roller commonly found in hardware stores, and they consist of a small plastic wheel mounted onto a piece of stamped metal with screw holes that work out quite nicely. You want to position the contact point for these wheels so that the contact the mill jars very close to their bottom edge.

Figure 10 shows an age-old method for mounting pulley drive motors which uses the weight of the motor to tension the belt. This is a simple method that eliminates the need for precise belt lengths and allows the belt to be easily removed when changing pulleys. Drill out the mounting holes on the pivot plate first, then test fit the motor. Screw the hinges onto the plate first and then fasten it to the back side of the table top with the motor removed. Be sure that the motors drive shaft will align with the upper pulley before securing the pivot plate.

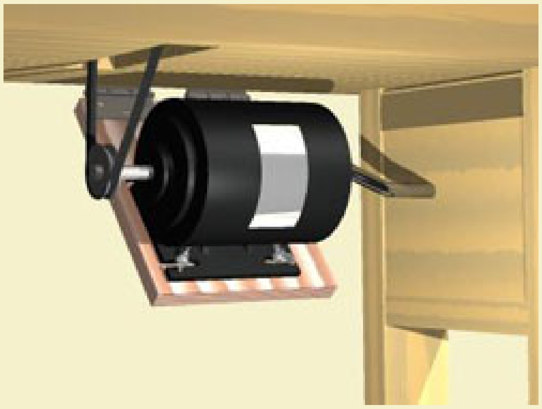

Figure 10: Motor mounted on hinged plate for a gravity tensioned belt.

Motors of the type required for this project can actually be obtained very cheaply from surplus dealers such as MECI, which is where I bought mine. I see a suitable motor on that site for only $16 at the time of this writing (part number 420-0362). While this motor doesn't have a starting capacitor, I have used the same motor in a star roller that turns a 50lb drum without any problems. You can go as low as 1/3 HP, but the trick is finding low RPMs. It is also ideal to try and find a motor with an integrated starting capacitor, since the initial load when starting the motor with a heavy mill jar can be high. The starting capacitor gives the motor an initial burst of power to get it going. Some motors specify the starting capacitor but do not come with it built into the motor. You must then buy the capacitor separately and wire it to the motor if needed.

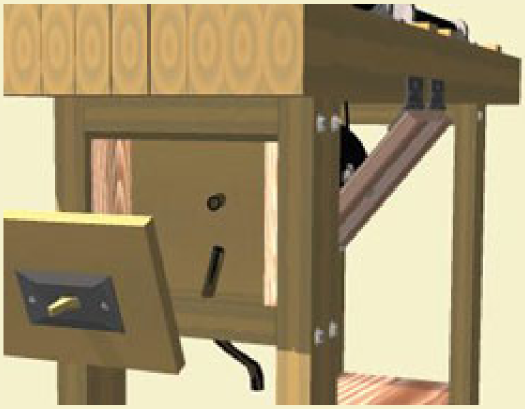

Figure 11: Wiring up the switch box.

With the motor attached, the last step is to assemble the switch box and wire everything into place. The motor will most likely have a wiring diagram labeled on it, which will require you to remove a panel and make some connections. Cut a section from your 8 ft power cord to wire a segment that reaches from the motor to the switch box frame. Be sure to leave extra wire as a "service loop" so that the motor can hang all the way down on the hinge plate without pulling on the wire. Allowing extra wire inside the switch box also allows the switch plate to be removed with enough space to get at everything.

Figure 11 shows how two 2-1/2" boards are screwed to the sides of the switch box so that the plywood face plates have something to fasten down onto. These can be screwed or simply glued into place.

At this point the basic mill is complete, but you may soon discover that ball milling is a rather noisy operation! For quieter milling, you can box in the milling table with a hinged lid that encloses everything. Lining the insides of this box with ceiling tile (including the lid) will dramatically cut down on noise during milling. The thick 2x4 table top makes it very easy to just screw some plywood around the sides for this purpose.

Happy milling!

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Design Notes...

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Ball Milling Theory

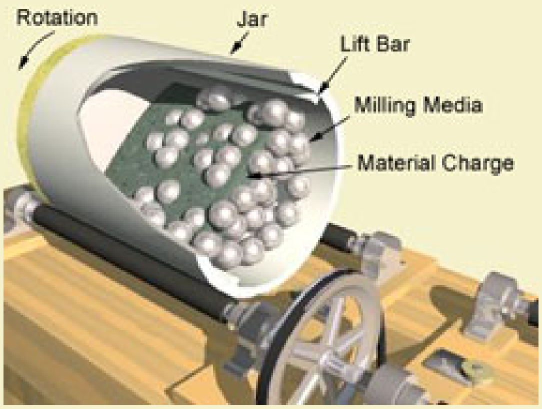


Figure 1: Ball milling terminology.

Introduction:
I was first given the formula for gunpowder by my Uncle at age 14, after he had observed my apparent obsession with class C fireworks. Being a scientist who had experimented with the ancient recipe himself during his youth, he thought I should try making my own fireworks. When I found out that these three simple ingredients could be purchased at the local drug store, I was ecstatic! It wasn't long before I had a box of Swan brand "flowers of sulfur", a pound of saltpeter and some charcoal briquettes I had ground up with a sledge hammer. Imagine my disappointment when the resulting greenish powder slowly burned with pools of bubbling white slag!

It wasn't until 14 years later with the publication of Lloyd Sponenburg's dissertation on ball milling in American Fireworks News (December 1995) that I was finally able to make commercial quality meal powder. Even though I had discovered the importance of using good charcoal through experimentation, my grinding efforts were previously limited to tediously grinding small batches in a marble mortar and pestle! I had read about the large wooden barrel filled with lead balls described by George Weingart in his book Pyrotechnics, but such a milling contraption seemed to be excessive for a small scale hobbyist.

With the better understanding of ball milling brought to the hobby pyro community by Lloyd's research in the mid 90s, many pyro hobbyists can now experience the joy of making high quality gunpowder without ever experiencing the frustrations of grinding by hand or the "CIA" manufacturing method (an alternative method of making BP that doesn't involve grinding). With Lloyd's ball milling book having sold over 2000 copies, there are probably over 1000 home built ball mills operating in just America alone.

This article borrows from Lloyd's research, which was obtained from the commercial ball milling industry, and explains some of the key design criteria for making your own ball mill. This is a good starting point for anyone interested in making their own black powder, which is the foundation upon which all other pyrotechnics have been built.

Grinding Theory:
There are a lot of misconceptions about what goes on in a ball mill. We know that a drum filled with heavy metal objects will grind powder when it is rotated, but how exactly does this happen? Some people think that the powder is pulverized against the sides of the drum as the media roll over top of it. Others believe the grinding media should drop down onto the powder grains from above, thus crushing it by impact. While there are "drop" mills that operate in this fashion, the use of high-impact methods are not recommended nor even necessary for effectively milling live batches of black powder.

The ideal milling method for optimized black powder milling involves what is called "cascading" action. This is a continuous flow of media

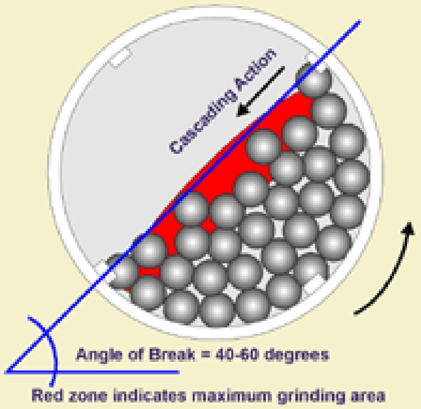

Cascading Action
Angle of Break = 40-60 degrees
Red zone indicates maximum grinding area

Figure 2: Optimal angle of break for cascading action.

Optimal Speed Calculator:

Enter the diameter of your milling media and jar I.D. below to get the optimum speed of rotation for grinding efficiency. You may also enter the media size and a rotation speed to determine the jar size for that combination. Calculations are performed as you type.

Jar I.D. (inches)

Media O.D. (inches) .75

Critical Speed (RPM)

Optimal Speed (RPM)

Drive Train Calculator:

Enter values for five of the six parameters below in order to solve for the missing parameter. You can use this to calculate the required motor speed by entering all drive train diameters plus the optimal speed calculated above.

Motor Speed:

RPM

Pulley #1 Dia.:

Pulley #2 Dia.:

Drive Roller Dia.

Jar Outside Dia.:

rolling over itself with the powder being sheared between them. Figure 2 shows the active grinding area for an optimally charged ball mill. As the drum rotates, the media should ideally form a sloping pile that maintains a 45 degree angle so that there is a constant cascading of media at the surface. Because the media is falling the fastest and for the longest distance at the top of the pile, the majority of grinding action takes place at the surface and diminishes the closer you get to the jar wall.

Optimized Rotation Speed:

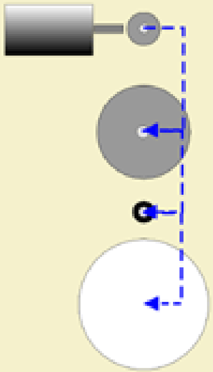
The speed at which the ball mill jar rotates is responsible for maintaining the slope of the cascading media pile, which is known in the industry as the "angle of break." This angle can be between 40 to 65 degrees as measured from the horizontal. If the angle is too shallow, the media will not cascade much from one end to the other. If the angle is too steep, the media will actually break free and fall from top to bottom while striking nothing in between. Still faster speeds can cause the media to centrifuge away from the pile and not cascade at all. The speed at which this begins to occur is known as the "critical speed."

Steep angles are caused from overly high rotation speeds, while shallow angles are caused from low RPMs or slippage of the media inside the jar. The slippage problem can be counteracted with the use of lift bars, as seen in Figure 2. These are traction bars that run the full length of the jar and act to support the media as it climbs the wall. At least two lift bars should be used in smaller jars, with four being used in larger jars. Jars that are multi-sided like hexagons or octagons usually do not have the slippage problem and do not need lift bars. rubber jars such as those used in rock tumblers also do not have the slippage problem.

The rotation speed of the jar required to obtain the optimal angle of break is dependent on both the diameter of the jar and the diameter of the media being used. The following formula can be used for determining the critical speed based on these two dimensions (diameter measurements must be specified in inches):

$$\text{Critical Speed} = \frac{265.45}{\sqrt{\text{Jar I.D.} - \text{Media O.D.}}}$$

The critical speed must be known in order to calculate the optimum speed, which is the speed that you actually want your jar to rotate at. The optimum speed varies as a percentage of the critical speed depending on the viscosity of the material being ground. For the dry powders used in pyrotechnics, the optimum speed will be 65% of the critical speed. Using the interactive calculator on this page will help you determine the optimal speed for your mill without having to reach for a calculator.



Jar Speed:

☐ RPM

Calculate

Once you know the ideal speed of rotation for your mill jars, you will need to design your mill around this critical parameter. With most ball mill designs, you have two areas of speed reduction to tweak: from the motor drive shaft to the drive pulley and from the roller bar to the milling jar. The drive train calculator featured on this page gives you a simple way to play with these numbers and find the dimensions you need. The numbers you enter are not tied to specific units (inches vs centimeters) but you must be consistent in the units you choose to use. Do not enter some numbers as measured in CM and other measured in inches. All numbers are assumed to be using the same units otherwise the calculations will be wrong. Start by entering the dimensions that are the most difficult to change, such as the jar diameter and the roller bar diameter. You can only solve for one number in the table, so five out of the six fields must contain a value before hitting the "calculate" button. Filling all four diameter fields and leaving the motor RPM blank will help you determine the ideal motor for your mill. If you already have a motor and you know the RPMs, you can enter it and then play with the other fields to find the best combination of pulleys, jar and roller diameters you need to get close to the optimal jar RPM.

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Ball Milling Theory

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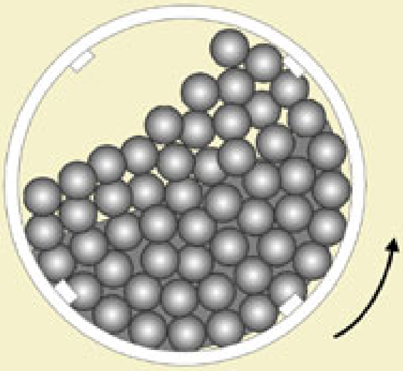

Figure 3: An overcharged mill.

Optimized Jar Loading:
One key to efficient milling is a properly charged milling jar. "Charge" refers to the amount of media and powder loaded into the jar, which is specified as a percentage of the overall jar volume. In order to maximize the cascading distance at the surface of the media pile, the jar should be filled 50% by volume with the milling media alone. This gives a cascading surface that is equal to the diameter of the jar, which is the maximum possible surface length. Too much media or too little will decrease the length of this cascading zone and increase your milling times.

There is a tendency by those using larger milling drums (such as 5 gallon buckets and other large diameter jars) to under charge the media to save money or time spent casting media, as well as to lighten the weight of the drum. Undercharging your mill in this manner will increase the milling times relative to a properly charged mill.

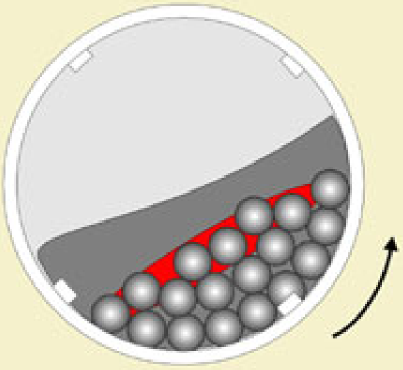

Figure 4: Undercharged media with overcharged load.

The material charge is equally important in running an efficient milling operation. If too little material is loaded with the media, it will mostly stay in the voids between the media and the media will just grind against each other. Too little material will cause excessive wear on the media while grinding very inefficiently. Too much material will also interfere with efficient grinding by creating a shock-absorbing cushion between the media. An overly high material charge is the most common mistake, since it is tempting to try and grind more powder at once. A jar with undercharged media will usually be overcharged with material, thus compounding the inefficiency with a combination of the reduced cascading zone in addition to the cushioning effect.

For most materials you will be grinding, a 25% material charge (relative to jar volume) is the ideal load. There are some exceptions to this, such as when milling fluffy mixtures containing a lot of air. The volume of a high charcoal mix tends to be inflated before grinding due to a large quantity of air trapped in among the light charcoal particles. As milling progresses, this air is forced out and the material volume decreases. To account for this fact, a higher material charge is necessary when milling mixtures containing charcoal and other compounds that seem overly fluffy.

Some experimentation is inevitable in determining the exact amounts of material charge to use. While the media charge should always be 50%, material charge will vary from 25% to 40% or more in some cases such as when grinding 100% homemade airfloat charcoal. The best way to tell if your mill is properly charge is to listen to it after about 15 minutes of grinding. You should hear a continuous cascading sound that is fairly loud. If the mill seems quiet or muffled, you are probably grinding too much material.

"24 Hour Meal" in 5 Hours:
Some BP makers prefer to grind larger batches less efficiently by running over-charged mills that typically involve open ended buckets or drums that spin at an angle to keep the material from falling out. The argument is that while less efficient mills are required to run much longer than a fine tuned closed-jar mill, they can mill a lot more powder at

once and thus reduce the frequency of emptying out the contents. While this argument has merit, I prefer to minimize the amount of time spent tumbling live batches of powder, which also extends the life of the mill and keeps the motor from overheating.

A fine tuned ball mill designed and operated as described in this article will allow you to produce what some people refer to as "24 hour meal" in about 5 hours of milling time. I prefer to mill the nitrate while also milling a parallel jar of the charcoal and sulfur mixed together in the 3:2 ratio for 2 hours. The two are then mixed together in a 3:1 ratio and milled for only one hour. This will give you a very fast burning powder in 5 hours (3 hours total run time with only 1 hour of milling the live mix) that is as fine if not finer than what the bulk-milling crowd had to run their inefficient mills for 24 hours to produce! 🔥

Further Reading:
Build A Ball Mill
Making Milling Jars
Casting Milling Media

REFERENCES:

"Ball Milling Theory and Practice for the Amateur Pyrotechnician,"
Lloyd Sponenburgh

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Tool Tip...

Page 1

Making Ball Mill Jars

Introduction:
Ball mill jars are an important part of the design of any ball milling system. There are as many designs for home made milling jars as there are ball mills. Perhaps the most widely used milling jar, made popular by Lloyd Sponenburg when first published in his well known book "Ball Milling Theory and Practice for the Amateur Pyrotechnician," is the type shown in Figure 1. This jar is made from 6" PVC pipe fittings, making it a rather quick and easy jar to make. A 10" segment of pipe is fitted with a solid end cap on one end and a reduction cap on the other end. A removable rubber cap is used to seal the jar using a pipe clamp.

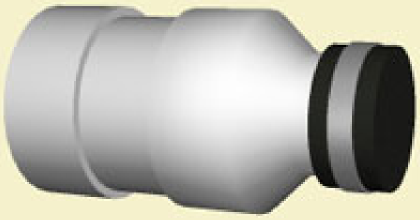

Figure 1: Standard "Sponen" PVC jar.

While this type of jar is easy to make, it has a few disadvantages. On the usability side, the small opening makes it difficult to extract large nitrate balls that can sometimes form when over milling KNO3 in a damp climate. It also makes it hard to clean off the sides of the jar when powder becomes caked to the sides. Due to the costs of the PVC fittings, it is one of the more expensive types of jars to construct. The total parts cost can run about $20 per jar, and one typically needs at least 3 jars when dedicating them to certain materials. While the jar is quite rugged and easily hosed off for cleaning, the strong construction results in a more powerful and fragmented explosion in the rare event of a milling ignition.

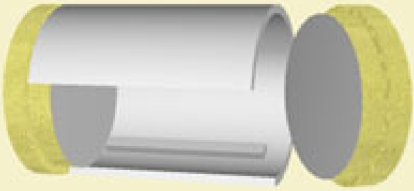

Figure 2: PVC jar with flush fitting ends.

The jar shown in Figure 2 uses the same 6" PVC body, only with home made end plugs. These plugs are cheap to make and allow full access to the jar walls when removing caked up powder. A rubber seal around the outside (not shown) prevents the powder from leaking around the edges of the plugs. The plugs are made from particle board and held in place by only two screws on each end. While my initial thoughts were that haveing end plugs that were not firmly attached could allow the jar to sustain an ignition without causing

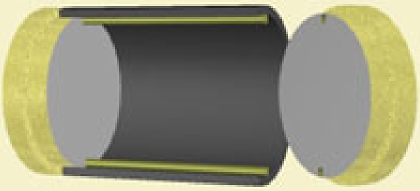

Figure 3: HDPE jar with brass rods for lift bars.

Mill jars that have been detonated under controlled conditions reveal that the lead media do not actually travel far at all. It is the fragmentation from the burst jar that is the greatest safety hazard. Figure 3 shows an even safer jar that is made from a segment of HDPE pipe instead of PVC. Since there are no adhesives capable of gluing anything to HDPE, the internal lift bars can not be fastened to the walls of the jar unlessed tapped and screwed from the outside. The design shown here shows loose fitting brass bars that slide into holes in both ends of the end caps. These holes do not run all the way through the caps, thus there is no extra areas to seal against potential powder leaks.

All three jars shown in Figures 1-3 must have at least two lift bars for efficient operation. Trying to save a little work by omitting the lift bars will result in longer milling times, as the media will lose some efficiency due to slippage along the pipe wall. Lift bars add extra crevices for powder to cake in, so you don't want to install any more of them than you have to. I have found that two works just as well as four, with considerably less powder caking problems.

The jar shown in Figure 4 is perhaps the simplest and cheapest type that can be constructed. A hexagon shaped food storage container with a large flip lid can be found in many department stores. This container happens to wedge nice and tight into a segment of 6" diameter PVC. The hexagon shape of the container eliminates the need for any lift bars, so you need only cut a piece of 10" long PVC pipe and wedge the container into it. A pipe clamp must be used to secure the lid from accidentally flipping open during operation. While I have not used this type of jar myself, I am guessing that some extra measures must be taken to prevent powder leaks from around the rim of the lid.

While this last method of jar construction is certainly cheap, fast and easy, it will not last very long before the soft plastic of the inner container wears through.

Since the jars shown in Figures 1 and 5 are easy to build, the remainder of this article will show how to make the type of jar with home made end plugs shown in Figure 2 and 6.

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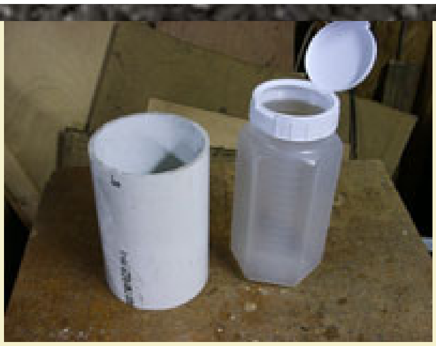
Figure 4: Hexagonal food storage container and 6" PVC sleeve.

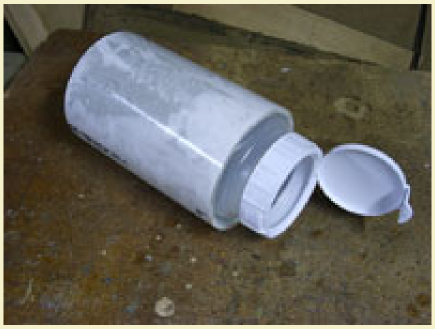
Figure 5: Container wedges tightly into sleeve.

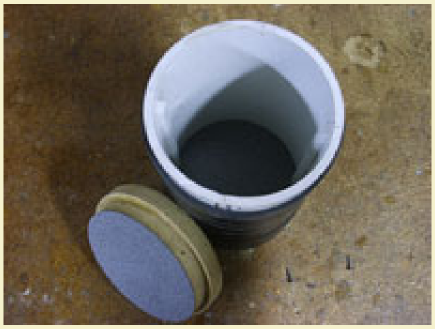
Figure 6: PVC jar described in this article.

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Making Ball Mill Jars

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Making the Lids:

Each lid required for this jar are made from two disks cut from 3/4" particle board. One disk is the diameter of the inside of the jar, while the other disk is the diameter of the outside of the jar. Both disks are glued together to form the finished lid.

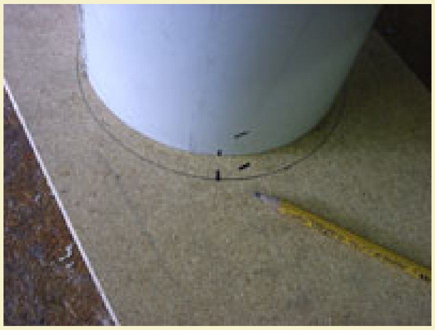

Figure 7: Tracing PVC ends onto particle board.

Begin by tracing the outside of your jar onto a piece of 3/4" particle board. Just in case there is any defect in the roundness of the jar, make an alignment mark as seen in Figure 7. The same procedure is repeated for tracing disks using the inside of the jar.

You will now need to cut out the two larger disks and the two small disks using something like a band saw or saber saw. Figure 8 shows some wood glue smeared onto one of the smaller disks prior to clamping it onto a larger disk. Three C clamps or other type of strong clamp are used to laminate the disks tightly together, as seen in Figure 9. It is important to make sure the smaller disk is centered on the larger one, otherwise the lid will have a lopsided overhang. Scrape away any excess glue that seeps out between the disks before it has a chance to dry, otherwise it will cause a gap when the lid is placed on the jar.

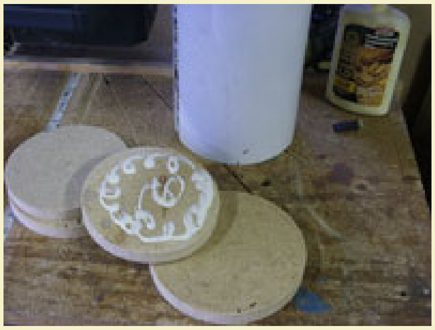

Figure 8: Gluing inner and outer disks together.

Particle board is being used because it is very flat, doesn't warp and will break away from the jar easily in the event of an explosion. It will deform if soaked with water though, so it may be desirable to coat the finished lids with polyurethane, Krylon or some other waterproofing.

The surface of the lid that resides inside the jar will be exposed to a lot of friction from the milling media. If the bare wood were not protected, there would be lost of wear and sawdust being chipped off into the compositions being milled. For this reason, a sheet of 1/16" Formica laminate is glued to the ends of both lids. This is the kind of material used on kitchen counter tops and is quite resistant to wear. Each lid should last several years before the laminate ever shows any sign of wear.

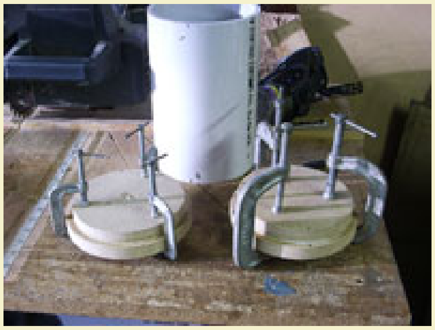

Figure 9: C-clamps used to laminate disks together.

Cut two pieces of Formica that are larger than the smaller side of the lid. These can be scraps obtained from a counter shop, wood shop or cut from a larger sheet available in home supply stores. A new sheet is usually 8ft x 30 inches and costs about $25, so try and find some scraps from a cabinet shop. The pieces do not have to be square or overhang by a certain amount. The overhang will be trimmed, so they only need to fully cover the bottom of the lid.

Formica laminate is attached using contact cement, which is a type of glue that is brushed onto both surfaces to be attached and then allowed to dry for about 15 minutes, as seen in Figure 10. The strongest type of contact cement is the "original" stinky stuff, not the newer low fume or neoprene based stuff.

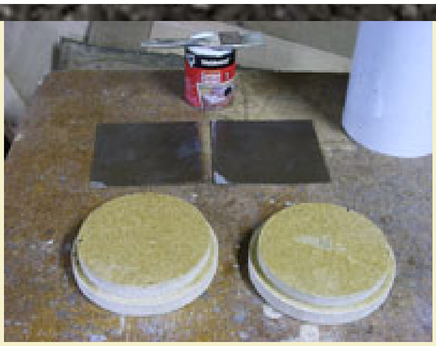

Figure 10: Applying contact cement to disks and Formica scraps.

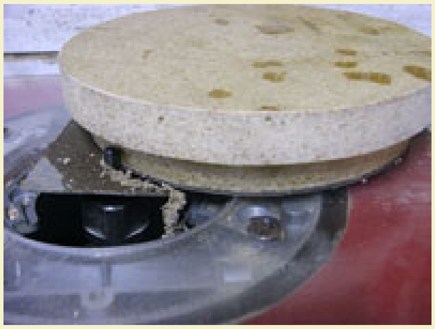

Figure 11: Using a router with a laminate bit to trim the excess overhang.

Once the glue is dry to the touch, the two pieces are pressed together. The pieces will permanently stick together and you can not slide them into position afterward, so make sure you position them correctly. Using a rubber mallet to tap down the Formica surface ensures that the pieces are well bonded.

After the pieces are glued together, the excess overhang can be immediately trimmed. This is done using a router with a special bit for trimming laminate. Figure 11 shows a router table with a laminate bit being used to trim off the excess laminate around the edges of the lid.

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Making Ball Mill Jars

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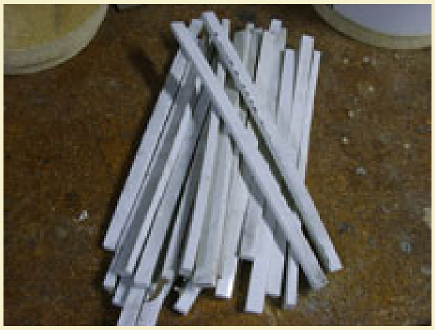

Figure 12: Lift bar strips cut from a section of the PVC pipe.

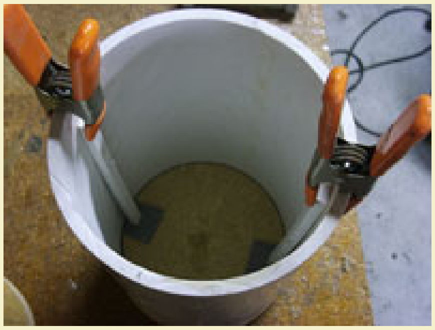

Figure 13 Gluing lift bars into place.

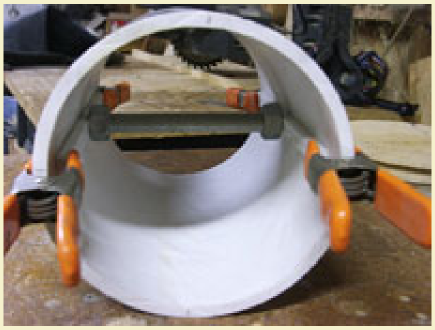

Figure 14: Using a threaded rod with two nuts to hold lift bars flat.

Installing Lift Bars:

Lift bars will substantially increase the efficiency of your ball milling jar. The purpose of lift bars is to prevent the media from sliding on the bottom of the jar as it rotates. This sliding action reduces the amount of tumbling that takes place, thus reducing the grinding action. The amount of slipping taking place during milling can actually be detected by sound. The idea sound of a well tuned jar is a constant clacking of milling media. Repeated patterns of clacking followed by silence is an indicator of slippage. Constant silence would be 100% slippage.

In this 6" diameter jar, two lift bars is all you really need to prevent slipping. The lift bars can be made by sawing 3/8" strips from a section of PVC pipe using a band saw. Figure 12 shows a pile of lift bars made in this way. The advantage to cutting lift bars form the same pipe you will be milling in is that the bars will fit the contour of the pipe wall. They are also made of the same material, so the PVC adhesive will hold them solidly to the jar wall.

For a 10" long jar, your lift bars will be about 8-1/4" long. If you make them too long then the lid will rest against them and cause a gap at one or both ends. Test fit both lids with the lift bars set in place to make sure they are short enough.

Before gluing the lift bars in place, use sand paper to rough up the bottom of the lift bars and the surface they will be glued to. Use standard PVC cement to coat the back of the lift bars, install one lid in the bottom of the jar, then hold the bars in place using spring clamps shown in Figure 13. The bars should com into contact with the jar lid at the bottom.

Attaching the Lids:

Next remove the bottom of the jar and secure the other side of the bars with spring clamps. In order to force the center part of the lift bars against the jar wall for a better glue job, use a section of threaded rod with a nut on each end so that the nuts can be spun out to apply force on each end. The threaded rod should fit between the lift bars with only a 1/4" clearance when the nuts are threaded all the way back.

Once the lift bars are dry, you are ready to attach both lids. These are held in place by 3/4" long brass or stainless steel screws, with two screws on each end. The screws should be the tapered flat head type, and they will need to be counter sunk into the jar wall so that they do not stick out. Drill the larger counter sink hole first, to a depth of about half the jar wall thickness. Drill the smaller through hole second, then install the lid and use the holes as a guide to drill a still smaller pilot hole into the side of the lid. The placement of these side holes should be 3/8" down from the edge of the jar.

The bottom lid of the jar will never need to be opened, so you can seal around

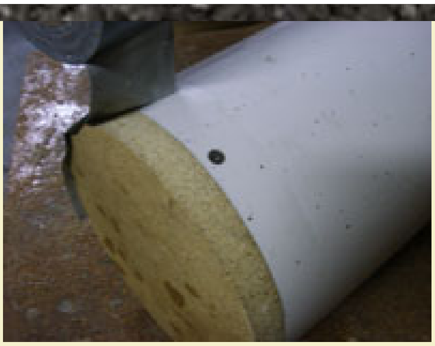

Figure 15: Attaching bottom with screws and sealing with duct tape.

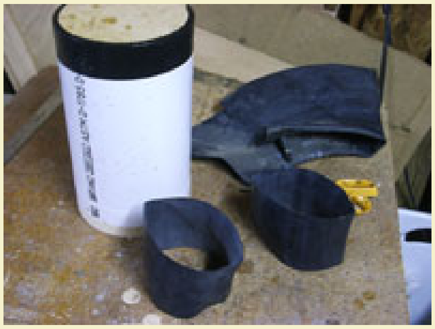

Figure 16: Rubber seals cut from an inner tube.

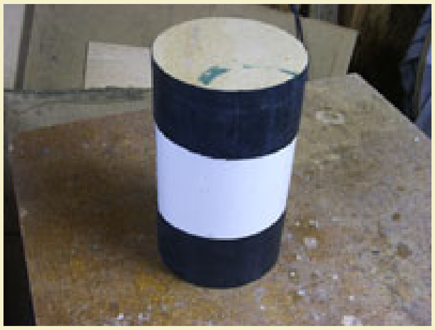

Figure 17: Rubber seals strapped onto both ends of jar.

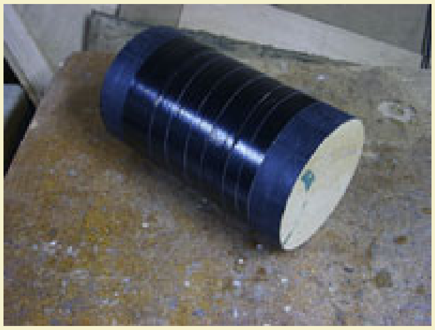

Figure 18: Duct tape wrapped around seals and jar to prevent sliping.

the bottom gap with a strip of duct tape as seen in Figure 15. This will insure that no powder will leak out during operation.

Finishing the Jar:
Next you will need to make two rubber seals using sections cut from a rubber tire inner tube. The inner tube I use measures 7" across when flattened down, and the bands are cut to be 3" thick. These bands are stretched over each end of the jar (with great difficulty I must admit) and aligned flush with each end. The purpose of these rubber bands is to seal the lid seam from leaking powder as well as to give the jar extra traction on the rollers and reduce wear on the ball mill roller bars.

Because the continuous forces experienced by the bands during use can cause them to slide around on the jar, they must be secured in place using duct tape. Figure 18 shows how one continuous piece of duct tape is wound starting from the middle of one band, across the jar and ending on the other band.

Figure 19 shows how the top seal is pealed down to access the screws when opening and closing the jar. You know have a ball mill jar that is leak proof, durable, explosion resistant, easy to open and clean and features no external nuts or bolt heads to catch on anything.

Design Notes:
When I first designed the jar shown here, it was my hope that an accidental ignition during milling or handling would result in the ends blowing out of the pipe instead of fragmenting the PVC. I recently detonated one of these jars at FPAGs Spring Festival as a demonstration, using an identical jar charged with real lead media and an 800g charge of fully milled meal powder. The jar was loaded, sealed up, fused and placed into a 2 ft deep hole in the ground.

To my surprise, the jar exploded violently into many fragments. The duct tape around the jar helped to reduce the number of fragments, but the jar was shredded all the same. The majority of the lead media was left in a hot pile at the bottom of the hole, but a few pieces did make it out of the hole and land a few feet away.

Due to the sheer amount of energy contained in a typical 800g batch of finely milled meal powder, it would be impossible to design a jar that would not seriously injure the user in the extremely rare event that it should detonate in his possession. It has been noted that PVC does not show up on x-rays, which would make any accident that ever occurred more difficult to operate on. The optimal choice of jar material from a safety standpoint would be a section of large diameter HDPE. Making a shorter jar from larger diameter pipe not only creates a bigger escape hole to vent the pressure during a detonation, it eliminates the fragmented PVC shrapnel issue. Since ball mill explosions are very rare, and explosions with the operator present are even more rare, the safety concerns mentioned here are really more about peace of mind than any real necessity.

Note that the milling efficiency of ball mill jars actually increases as the diameter increases, but only when you have it properly charged with 50% by volume of media. This is because the milling action takes place on the angled slope of the media pile. So the longer that slope is then the more milling will take place per revolution. The length of this slope is equal to the diameter of the jar, so as the diameter increases then so does the amount of powder being ground up. Thus if two jars have the same volume, but one is a shorter jar with a bigger diameter and one is a longer jar with smaller diameter, the short and fat one will actually mill faster.

Since an 8" diameter jar that is only 5.5" long has the same milling capacity and media charge as a 6" diameter jar that is 10" long, using the shorter 8" jar would not only result in faster milling, but would allow you to fit more jars on your milling machine at the same time!

For an improved milling jar over the one described in this article, I recommend cutting a 6" segment of 8" HDPE mortar pipe and plugging the ends as already described. Brass or aluminum bars can be locked into the end disks as seen in Figure 3. This will give you a safer, compact and more efficient jar to work with.

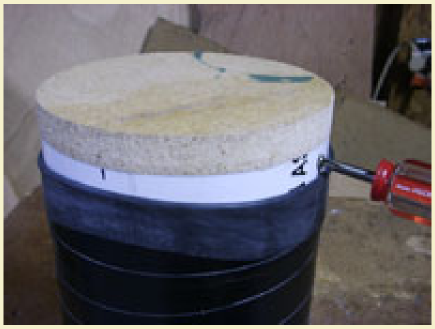
Figure 19: Rubber seal pealed back on working end of jar to access the two screws.

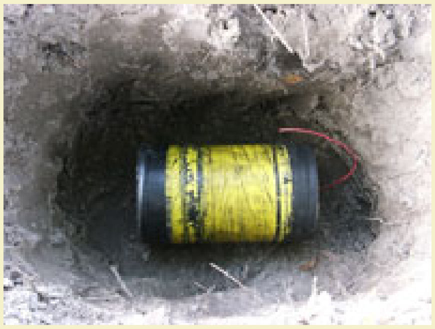
Figure 20: Simulating a mill explosion with a live jar.

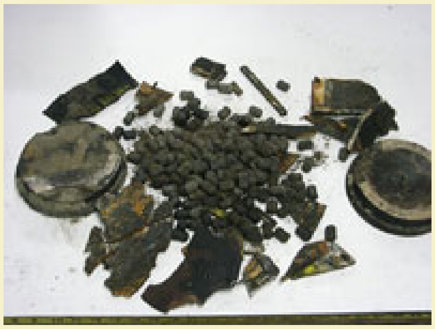
Figure 21: The fragmented remains of the ball mill jar after detonation.

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Technique...

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Casting Ball Milling Media

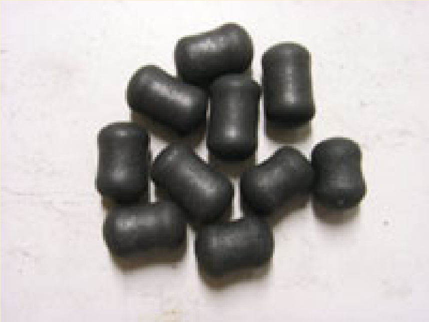

Figure 1: Lead media after substantial usage.

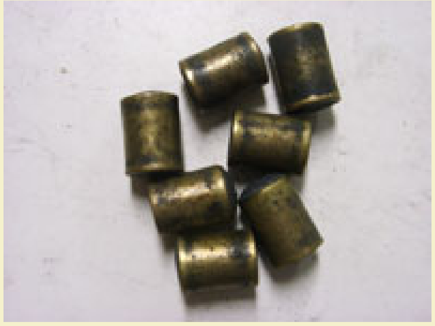

Figure 2: Lead filled brass after substantial usage.

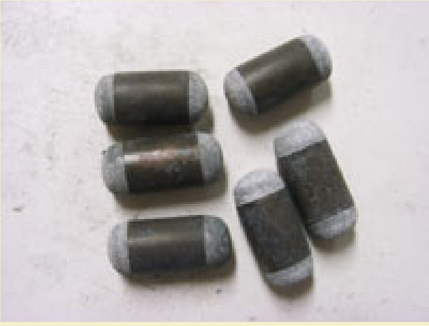

Figure 3: Lead filled brass with rounded ends.

Introduction:

Ball milling is by far the most popular method among fireworks hobbyists for grinding raw chemicals and making black powder. This method employs jars full of small balls or cylinders, known as "media" in the milling trade, which are tumbled in milling jars filled with composition.

There are several different materials commonly used to make ball mill media. All of the types mentioned below have various trade-offs, but they will all effectively pulverize your pyrotechnic materials.

Ceramic Media:

The most common commercially made media is made from various types of ceramic. Ceramic media can be purchased in a variety of shapes and sizes, including radius ended cylinders, balls, cones, ribbed balls and others. Ceramic media features very smooth and hard surfaces that optimize milling. It is also the most common option for those who can not manufacture their own media.

Some people have reported chipping problems with ceramic, but in general this is not an issue. Ball mills do not mill via impact, unless they are improperly designed, so this is generally not a problem. Media with sharp edges or other surface features prone to chipping should not be used.

The most commonly raised concern about milling with ceramic media is the risk of sparking. There are many types of ceramic media, and some may contain silica particles which could produce sparks, but for the most part this is not a problem. The key is to know the type of media that you have and purchase it from a well known manufacturer such as CoorsTek, who claim that their media does not spark.

Even when using a non-sparking type of ceramic media, milling metals such as titanium or steel could result in impurities becoming lodged in the ceramic pores, contaminating the media with impurities that introduce a sparking hazard. While used ceramic media can be purchased for under $3/lb from some suppliers, the lack of knowledge about prior use would raise concerns in this area.

Another test you can perform is to take your media into a dark room and strike it against each other to check for visible sparks. Some people have reported orange sparks during this test, while others report nothing. Note that some forms of light output known as triboluminescence actually produce "cold sparks" that are incapable of causing accidental ignition. However, any visible sparks should cause concern.

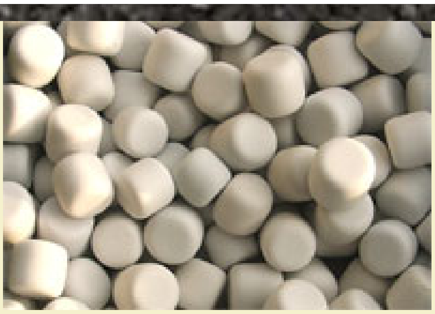

Figure 4: Ceramic media.

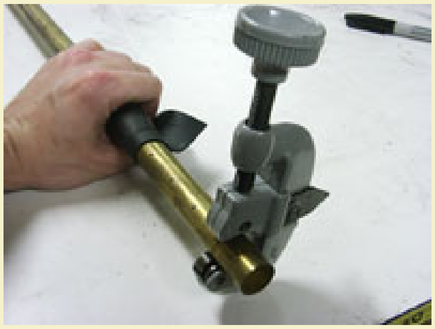

Figure 5: Cutting 1" segments from a long brass tube.

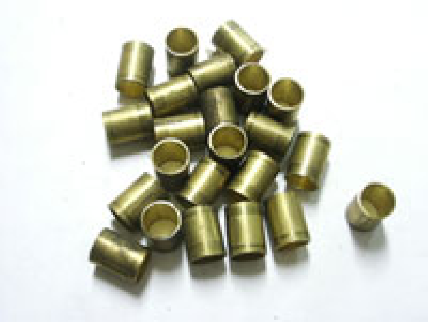

Figure 6: 140 segments required for one 6" jar.

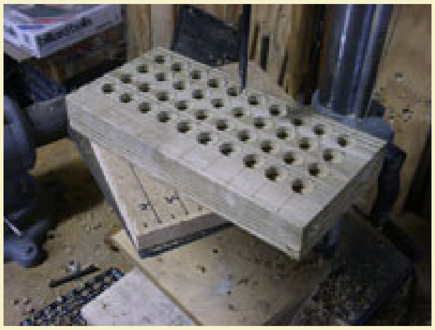

Figure 7: Drilling out the tube holding fixture.

Lead Media:
Lead media is probably the second most common milling material, mainly because it is cheap and easy to melt and cast. Because lead is so heavy, it grinds with more force than other types of media. Lead does not produce any spark risks and can be used to mill any type of pyrotechnic compound.

The surface of lead is very porous, which reduces the grinding efficiency by trapping pockets of material that do not get ground. Because lead is such a soft metal, it tends to wear away over time. This has raised concerns by some who fear breathing the smoke generated by components made from meal powder contaminated with lead during milling.

The amount of wear and surface deformities can be reduced by using lead hardened with antimony, as opposed to pure lead. Figure 1 shows some lead media made from tire weights after two years of extensive use. The mushroomed ends show how the lead changes form over time, since they were originally flat ended cylinders. From an efficiency standpoint, there is no noticeable difference between the milling time of this media when compared to the brass media pictured below it.

Brass Media:
Brass media is also a popular choice, since brass bar stock can be purchased and cut into small segments to use as media. Brass doesn't spark, is still fairly heavy, resists corrosion and has a smooth grinding surface. The only down side is the presence of copper in the metal, which can react to form sensitive byproducts when milling certain chemicals such as ammonium perchlorate.

Stainless Steel Media:
While not very commonly used, stainless steel is perhaps the best media available. Stainless doesn't spark, has a very smooth surface, is heavy, is resistant to wear, is resistant to corrosion and can be used to mill all types of chemicals. There are many different types of stainless, but the ideal grade should be copper free and high in nickel-chrome content, such as 310S24 or 316S16. Having a machine shop produce 140 pieces of 3/4" stainless media about an 1" long and rounded on both ends might be an expensive way to go, but the resulting media would last a lifetime and perform quite well.

Lead-Brass Hybrid Media:
The media described in this article combines the best characteristics of brass and lead, while also making the method of production easier. Brass sleeves are filled with lead, resulting in a smoother and deformation resistant media that leverages the increased weight and low cost advantages of lead.

Figure 2 shows a flat ended cylinder shape, whereas Figure 3 shows a version where the lead was cast to give spherical ends. The rounded ends help to lock the sleeve in place, hide the sharp edge of the brass sleeves and reduce compression stress that can cause the sleeve to mushroom after a long period of use. While the rounded ends are also supposed to increase milling efficiency, there is no noticeable difference. The rounded ends also expose more lead to the grinding process, which can result in more lead contamination.

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Casting Ball Milling Media...

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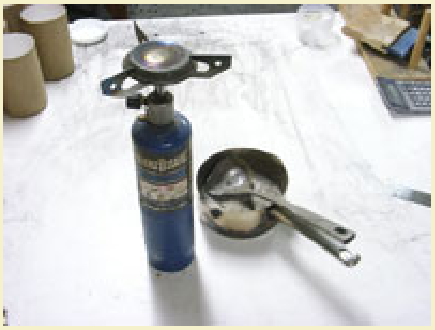

Figure 8: Propane camping stove and melting pot.

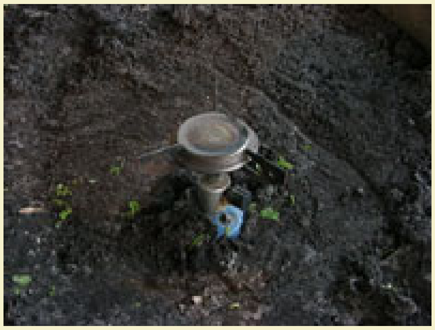

Figure 9: Buring the gas tank to keep melting pot low and stable.

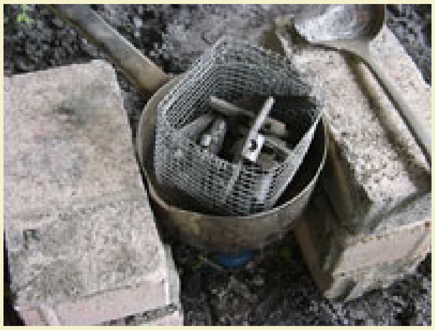

Figure 10: Using a cage to extract metal tabs from tire weights after melting them.

Casting the Media:

A typical milling jar measuring 6" diameter and about 9" long has a volume of one gallon. The proper media charge for ball milling is generally 50% of the jar volume. Using less than this amount in an attempt save on media or grind more material at once will greatly increase milling times. The 50% rule, when used in conjunction with lift bars in your milling jar, has been determined to maximize the milling efficiency by maximizing the slope of the tumbling pile of media when inside the jar (known as the "angle of repose" in the milling industry). The greater this slope is, the more aggressive the cascading action is and the faster your powder will be ground.

To make enough media for a one gallon jar, you will need to fabricate 140 individual cylinders measuring 1" long and 3/4" diameter. This will also require about 22 lbs of lead to fill all the cylinders.

The most tedious part of making a batch of media using this method is cutting the 140 sections of 1" tube. The brass tube used here were purchased in six foot lengths from McMaster Carr. The tubes are 3/4" O.D. with a .065" thick wall. The thinner tubes will not hold up under the stresses of milling and will crack off after a while, so be sure to use at least the .065" wall thickness.

Begin by marking a cutting point every 1" on the pipe, then use a pipe cutter as shown in Figure 5 to cut each segment. The pipe cutter helps to round over each end, which takes the edge off and keeps the lead from falling out once it is poured inside. If you straight cut the tubes using a hack saw or cutoff saw, the lead will get knocked out of your tubes during use (unless you make the type of media shown in Figure 12 and 13, in which case the lead overhangs the end of the tube wall). Using a piece of rubber will help you grip the tube in one hand while cutting all these segments. Figure 6 shows a couple feet of tubing converted into media casings.

Once all the tubes are cut, a fixture is needed to hold them while they are being filled with lead. This is easily made by drilling a bunch of 3/4" holes into a piece of scrap wood. Don't make the holes deeper than 1/2" or it will be difficult to remove the tubes after they have been filled. If you use a spade bit to drill the holes, you will need to fill the pointed cavity at the bottom with plaster or wood putty before you use the plate, other wise you will have big spikes on one end of your media after pouring them. The other option is to leave the holes and cut the spikes off after they have been poured.

The lead can be melted in a metal cooking pot using a propane camping stove as seen in Figure 8. A metal ladle is also required for transferring the molten lead into each mold.

Working with molten lead is a dangerous activity that requires several precautions. Because dangerous lead fumes will be generated, this activity should only be done outside. Gloves, eye protection, a good respirator and long sleeve pants/shirt are mandatory at all times in the presence of molten lead. The lead pot should be kept as low to the ground as possible and firmly secured to keep it from getting knocked over. I prefer to bury the propane tank and surround the pot with bricks in order to lock it in place (see Figure 9 and 10).

Because I am using tire weights for the source of lead, the metal tabs must be removed after the lead is melted away. I do this by fabricating a basket out of wire screen scraps, as seen in Figure 10. The basket is filled with tire weights, then lowered into the pot using a pair of long metal tongs. When the lead melts away, the basket is removed and the remaining metal tabs are dumped out.

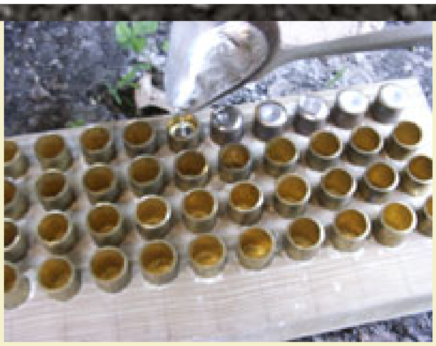
Figure 11: Using the ladel to pour each tube.

Figure 11 shows the holding fixture loaded with brass sleeves that are being poured with lead. Scrape away any slag on the surface of the lead before scooping up a ladle full for pouring. Since the lead will actually shrink some upon hardening, it is best to fill each tube half way and then go back and fill them the rest of the way with a second pour. When topping them off, fill them as high as possible so that the lead actually bulges beyond the rim of the tube. Avoid falling short by a small amount from the top of any tube, as adding a small second pour after the previous lead hardens usually results in a poor bond between the two layers. This can result in the added lead actually breaking away from the end during milling.

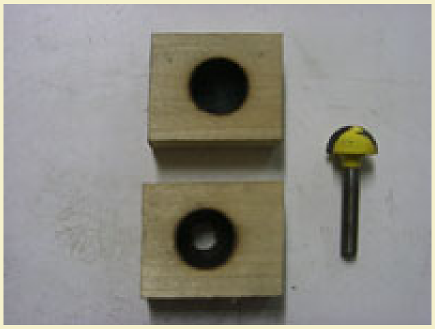
Figure 12: Rounded molds made with a plunge router and a 3/4" half round bit.

Any tubes that are not filled to the top after the lead hardens can be repaired by pouring a small amount on top, letting it solidify and then re-heating it with a blow torch until both the new lead and the lead underneath it melt together. Extra caution should be used when doing this, as trapped moisture can sometimes cause the lead to "boil" or splatter.

Once all the cylinders are filled, they will remain hot for quite some time and the wood around them will begin getting charred. I prefer to use vice grips to remove each cylinder and throw them into a bucket of cold water so I can start the next batch. The first batch of cylinders will be a little hard to remove, but successive batches get easier.

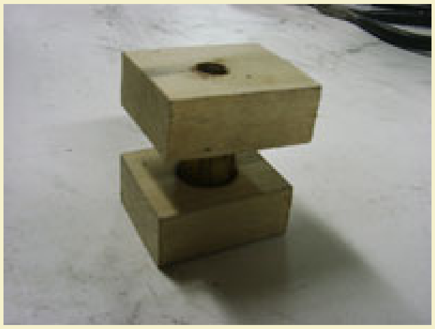
Figure 13: Capping both ends of a brass tube with the half round mold blocks.

Making Rounded Ends:
If you want to make media so that each end is rounded, a special set of rounded molds are made that fit onto each end of the brass sleeve. These molds are cut into scraps of 3/4" thick wood using the half round router bit shown in Figure 12. A plunge router with a depth stop is used to make many holes in a larger piece of wood, then the wood is cut into squares so that each square had a single rounded hole in it. Half of the molds are then drilled with a 1/4" hole, which is where the lead will be poured.

Figure 13 shows how the mold set is used. The sleeve is sandwiched between the two molds, which is then set into a bedding of sand while the lead is poured through the small hole in the top. Since the wood gets pretty charred by the time you make a dozen pours, the mold gets too lose after a while and must be discarded.

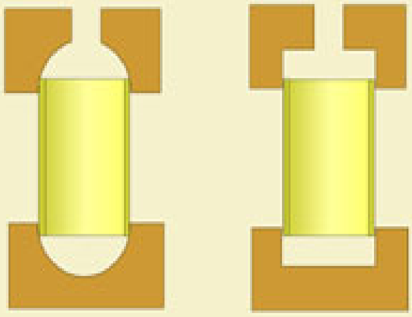
Figure 14: Two types of molds for creating radius ended media.

If you don't have a plunge router, you can still make radius ended media by using the second mold profile shown in Figure 14. This mold is created by simply drilling a cylindrical cavity and inserting the tube only partially into it. The media will have squared off ends when first cast, but these will be quickly beat into a spherical shape after using them in your ball mill. The nice thing about this method is that it lets you control the length of the lead that extends beyond each end of the tube.

It will likely take you the better part of a day to make your own batch of milling media. This may seem like a lot of work when you could just go buy some ceramic media. Then again, you could just go buy your own fireworks as well, so take pride in your hand crafted media and happy milling!

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Technique... **Page 1**

Casting Milling Media

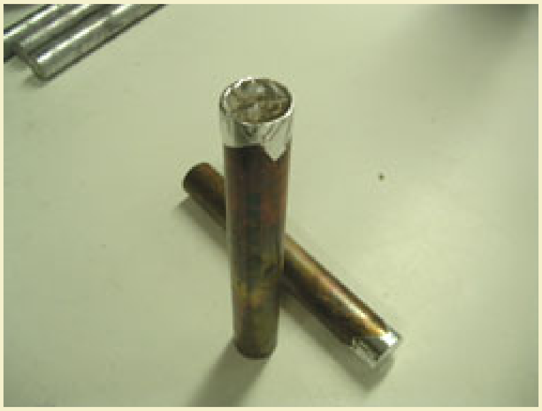

Figure 1: Six inch lengths of copper tubing with foil tape plugging the bottom.

Introduction:

Milling media cast from lead is a popular choice for do-it-yourself mill designers, mainly because it is cheap and easy to melt and cast. Because lead is so heavy, it grinds with more force than other types of media. Lead does not produce any spark risks and can be used to mill any type of pyrotechnic compound.

Tire weights, flashing, fishing sinkers and many other common sources of lead are pretty soft and will erode over time if they are used to produce milling media. Compositions milled using soft lead media are a possible health concern, as the lead wears off into the powder and then becomes airborne in the smoke generated when the powder burns, possibly exposing anyone breathing the smoke to traces of lead that can build up in their body over time. No studies have been done, thus it is hard to say how much lead you would likely be exposed to or if the risk is statistically noteworthy, but the possibility is there.

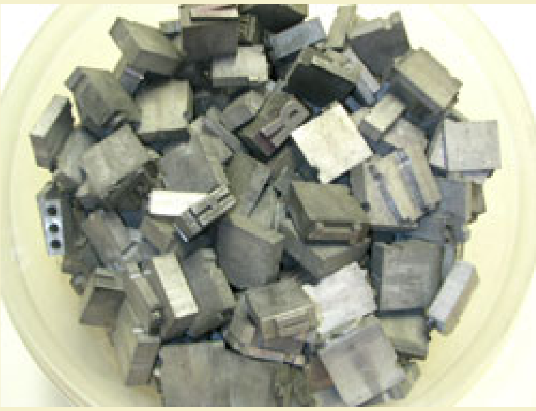

Figure 2: Twenty five pounds of Linotype lead scrap purchased on eBay.

In a previous article on casting milling media located here, a method was described of filling brass tubes with melted lead tire weights. The brass sleeve idea got around the erosion problem by encapsulating the lead in a sleeve of harder material, which also boosted the milling efficiency of the media. However, there are a few drawbacks to this method that are worth mentioning. The biggest problem is that over time, perhaps two or three years, the brass sleeves will start to crack and start separating from the media. It is thought that the constant pounding acts to harden the brass and make it brittle. When they crack, it is one pretty straight crack that runs the full length of the media, then it is only a matter of time before the inner lead falls out. Of course all sleeves don't crack at the same time, so over a long period you get a mixture of progressively more bare media as more and more sleeves crack off. This type of media is also more difficult to produce because you have to cut a segment of tubing for each media segment. So every couple of years you would have to cut all new sleeves, re-melt the old lead and cast all new media. A third disadvantage is the undesirable presence of copper in the brass sleeves if they are being used to mill Ammonium Perchlorate.

One solution to the above mentioned problems is to use stainless steel sleeves, which are hard, non sparking and very corrosion resistant. However, they are also more expensive and more difficult to cut. When using soft lead, however, stainless sleeves are the best option.

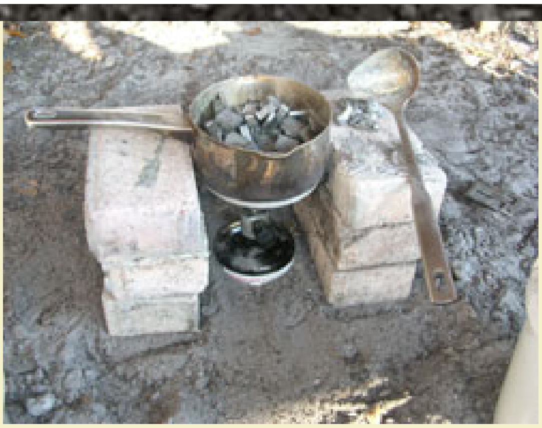

Figure 3: A melting pot made with a Colman propane stove and bricks.

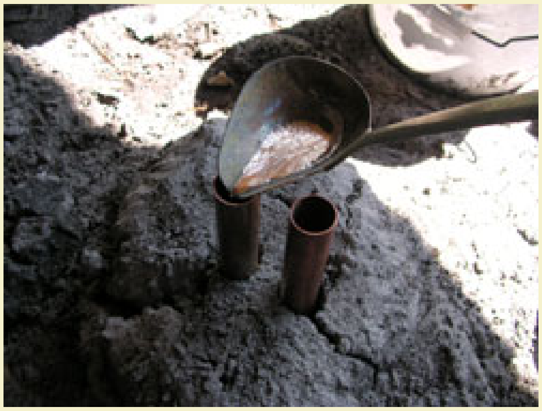

Figure 4: Filling copper pipes buried in the sand.

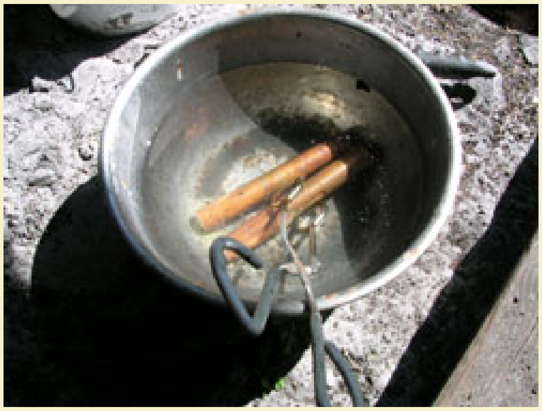

Figure 5: Cooling off the lead in water after it solidifies.

Another solution is to use a harder grade of lead and just cast solid media without an external sleeve. An ideal source of hard lead can be found as scrap from the printing industry under the name of Linotype lead. These are usually little blocks of lead with letter faces on one end, which fit into a printing press for stamping out text or other characters. The lead is considerably harder than tire weights or fishing weights, and those who have been milling with Linotype media report virtually no erosion over time. The media described in this article is made using Linotype lead.

Finding the Lead

Linotype lead is apparently scrapped from printing operations on a regular basis, as there is no shortage of it for sale on eBay at any given time. Figure 2 shows a 25 pound lot of Linotype that was purchased on eBay for $18 plus $8 shipping. Linotype is surprisingly easy to find on eBay, as many people buy it for casting their own bullets. It is usually sold in 25 pound lots because that is the maximum amount that can be crammed into a Priority Mail Flat Rate box for $8 shipping cost. It's a bit surprising to see the battered paper envelope straining under the 25 pound load actually survive the trip to your mailbox, but the system seems to work! Just one more example of life made better by eBay.

Melting the Lead

The simple setup I use for melting lead is shown in Figure 3. A Colman propane tank is fitted with a screw-on stove burner that can be found in any store that carries camping supplies. The tank is buried in the ground for stability, then some bricks are used to build up a wall around the sides to help keep the melting pot from falling off. Any all-metal pot can be used to contain the lead, just make sure it doesn't have any kind of non-stick surface or any other kind of coating inside. The types with aluminum or copper bottoms will help to transfer heat faster, but will still work with just a cheap no-frills pot. A metal ladle is also required for transferring the lead from the pot to your mold tubes.

Making the Molds

I had heard of people rolling tubes from paper and aluminum foil and using these to produce long rods of lead that were then chopped down into smaller pieces. This seemed like a good idea to me, but I get poor results with this method. If the inside portion of the tube is rolled from aluminum foil, the aluminum tends to expand and crinkle when the hot lead fills it, giving you deformed surface textures and even foil that gets embedded inside the lead. If paper is used on the inside of the tube, a porous texture results on the surface of the lead bars. Both defects are undesirable and difficult to prevent. Not only that, but you have to roll a bunch of tubes before hand and then spend time trying to unravel their charred remains from the finished bars.

A far easier method is to cast the lead into lengths of copper plumbing tubes. For my own media I use 3/4" I.D. tubes cut to six inch lengths. Twenty five tubes of this size will produce all the media you would need to charge one standard size 6" Sponen PVC jar.

The pipes should be cut with a hack saw or cut-off saw, not a rotary type pipe cutter. The rotary pipe cutters will reduce the pipe diameter at the edges, which will trap your lead bar inside. After cutting the pipes, a de-burring tool should be used to clear the inside edge of the pipe from any debris that could prevent the lead bar from easily sliding out. You may prefer to only cut twelve fill tubes and then do two fills, or you can just go ahead and make all twenty five or however many you need to cast all the media you need in one fill session. The nice thing about these copper tubes is that you only have to make one set, then you can keep reusing them to cast all your media in the future.

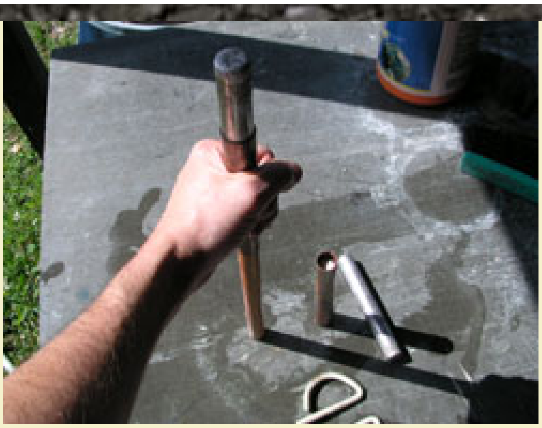

Figure 6: Removing the lead bars from the tubes.

Casting the Lead

It is a good idea to spray the insides of each tube with a lubricant like WD-40 prior to each casting, which helps the lead bars slide out of the sleeves when completed. The WD-40 will not boil or catch fire during the casting, but it will leave small dimples in the surface of the finished bars. The dimples will get hammered out during milling however. While sometimes the bars will eject without lubricant, more often they will get stuck and trying to pound them out only makes them more stuck.

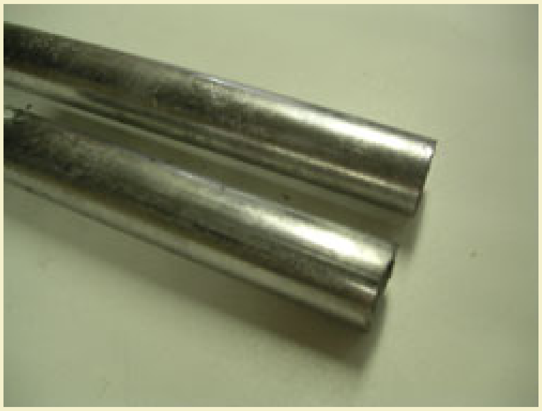

Figure 7: Smooth lead bars ready for segmenting into media.

Next the tubes are prepared for casting by first fixing a square of foil tape to the bottom in order to keep the lead from running out, as seen in Figure 1. A good quality, thick foil tape should be used so that the lead can not burn its way through. It is also a good idea to wrap another piece of foil tape around the bottom of the tube so that it seals around the edges of the tape that was applied to the end, otherwise the weight of the liquid lead can sometimes cause it to leak out through the wrinkles in the foil and make a mess that ruins the casting.

The tubes are filled by first inserting them into sand at least half their length, as seen in Figure 4. The molten lead is then poured in using the ladle. It is not a problem if it takes two or three fills from the ladle to fill the tube, just don't let one fill solidify before adding the next. This process is a bit hazardous, so be sure to wear long jeans, a long sleeved shirt with thick material, gloves, safety glasses and a good respirator to protect against lead fumes. Obviously this is a process that needs to be done outdoors.

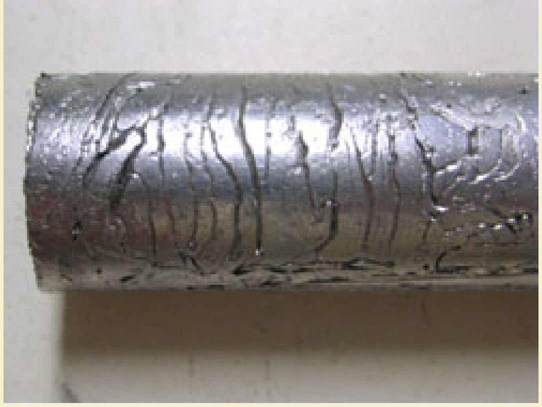

Figure 8: Defect from pouring with lead that isn't hot enough.

It is important to let the lead solidify before moving the tubes, so just let them sit a good fifteen minutes minimum. Once they set up, you can use tongs to transfer the tubes into a tub of water to speed up the cooling process, as seen in Figure 5. This step can be skipped if you just let the tubes sit for several hours after casting.

Surprisingly, the lead does not adhere to the inside of the copper tube at all-especially if the inside was coated with a lubricant. To remove the lead bars, a wood dowel rod is placed on a table and the lead filled tube is placed on top of it. The tube and dowel rod are held together and hit down against the table surface, using the weight of the lead as a hammer. This will push the lead from the tube as seen in Figure 6. Care must be taken not to use too much force when pushing the bars out, otherwise the lead can get compressed and expand sideways-resulting in the bar getting permanently stuck inside the tube. When this happens you will need to heat the entire assembly to recover the lead and then discard the copper tube.

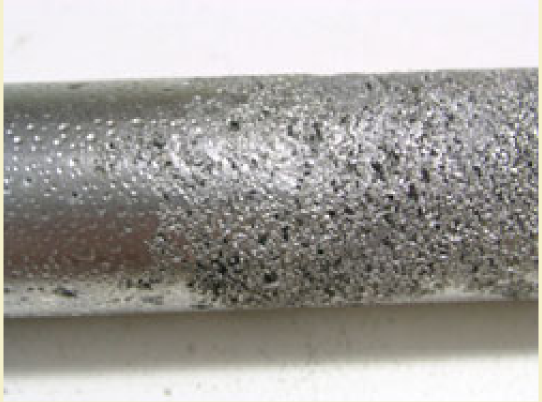

Figure 9: Defect that occurs with certain types of linotype lead.

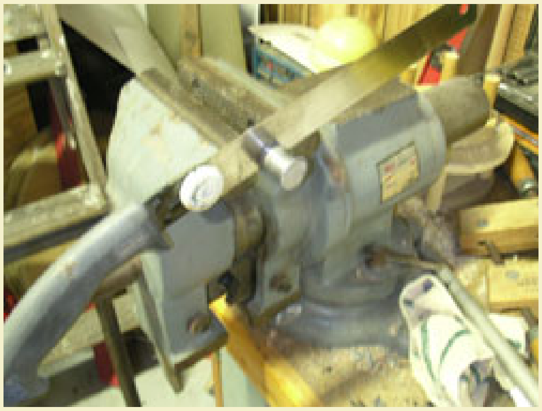

Figure 10: Using a Japanese hand saw to make rapid cuts through the lead.

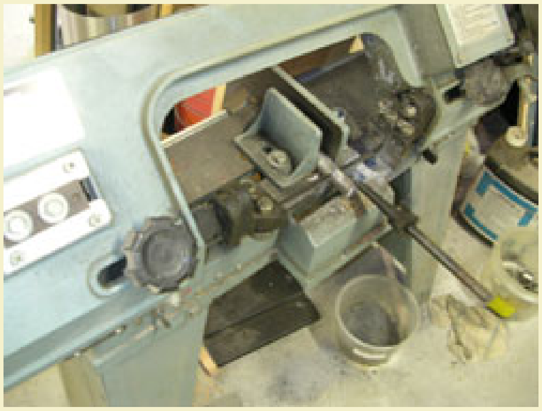

Figure 11: Using a cut-off band saw to make even more rapid cuts.

There are two types of common defects in the castings that you will run into. The first one shown in Figure 8 is a wrinkly texture that usually occurs near the bottom of the bar. This defect occurs when the lead hasn't been sufficiently heated prior to pouring. The copper pipe and surrounding sand will absorb heat rapidly from the lead when it first enters a cold tube. This causes the lead to solidify right away, causing the wrinkles as new lead falls on top of it. This is a simple defect to avoid.

The second type of defect only occurs with certain types of linotype lead. A rough, porous surface will form at the top end of the lead bar as seen in Figure 9. This type of defect will not fix itself during milling so it must be discarded and returned to the melting pot. It seems the harder the lead is, the more this phenomenon occurs. It's almost like some component of the lead is floating to the top portion of the lead bar as it cools, since this defect always occurs in the top 20% of the bar. When pouring with this kind of lead, you just have to accept the fact that 20% of each pour will be unusable.

Occasionally you will find that a void forms in the end of the bar due to shrinkage as the lead cools. Media that has holes in the surface that lead to internal voids can be salvaged by filling the internal void with hot glue, otherwise just melt these pieces back down. Do not mill with exposed hollows in your media, otherwise chemicals will build up inside that could cause contamination problems later.

Finishing the Media

Figure 7 shows the smooth, shiny surface of the lead bars, which makes an ideal milling surface. You don't want to see air bubbles or other concave indentations on the sides. The ends will be a bit messy, and you will have to peel off the aluminum tape or burn it off, but these areas will pound themselves into a smooth surface once you start milling.

The last step is to cut the longer bars into the shorter segments that you need. This can be tedious if you try hand cutting them with a standard fine tooth metal cutting saw, which cuts very slowly. A better choice is the thin kerf Japanese type hand saws seen in Figure 10, which will cut quite fast. An even better tool is a cut-off type band saw if you have one, which is seen in Figure 11. These have a depth stop that allow you to make all cuts to the same length without having to measure out cutting marks on each one.

The finished media is seen in Figure 12. I like to sand the sharp edges on a vertically mounted belt sander after cutting the media, but these will also pound themselves round during milling if you just leave them as-is.

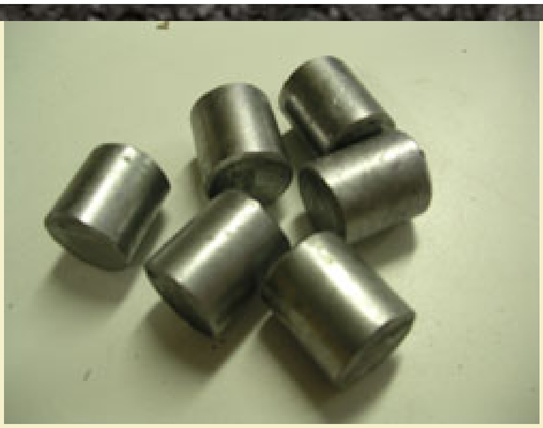

Figure 12: Finished media ready for use.

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Tool Tip...

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Build Your Own Corning Machine

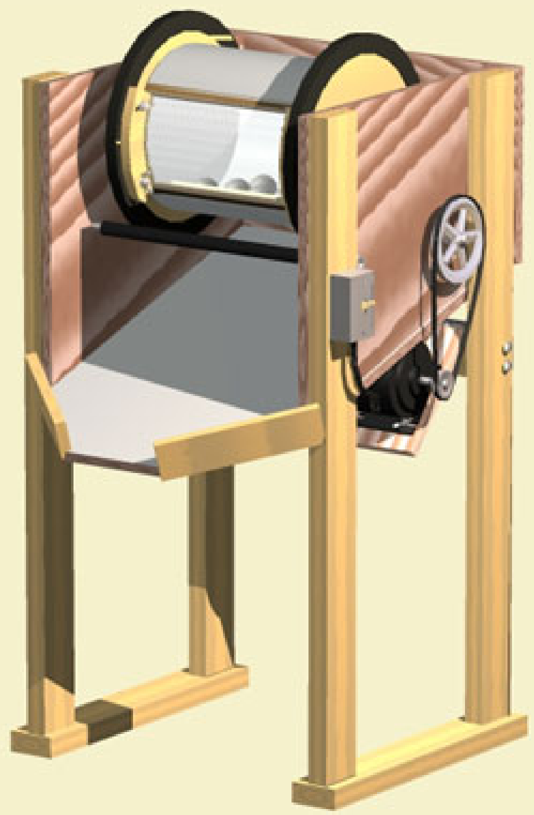

Figure 1: A simple corning machine that screens as it corns.

Materials:

- (4) 48" 2x4s
- (2) 24" 2x4s
- (1) 23" 2x4
- (2) 11-3/8" long 1x4s
- (1) 26" x 14" 3/4" plywood
- (2) 23" x 22" 3/4" plywood
- (1) 32" x 23" 3/4" plywood
- (2) 16" diameter disks 3/4" plywood
- (2) 11" diameter disks 3/4" plywood
- (1) 14" long 1/2" wood dowel
- (4) 14" x 1/4" x 3/4" wood strips
- (1) 10" x 14" screen
- (12) 3-1/2" long 1/4" lag screws
- (12) 1/4" washers
- (1) box 1.5" #8 wood screws
- (1) 8" pulley
- (1) 2" pulley
- (2) 2" swivel casters
- (1) 26-3/4" long 5/8" rod
- (1) 24-1/4" long 5/8" rod
- (4) 5/8" collars
- (4) 5/8" ball bearings
- (2) 21" long 5/8" I.D. heater hose
- (2) 3" hinges
- (1) 14" long 11" I.D. tube or pipe
- (4) 2" long 1/4" stainless bolts
- (4) 1/4" stainless wing nuts
- (1) 32" bike tire innertube
- (1) switch box
- (10) pool balls
- (1) 4L400 40" drive belt

Unmeasured:

staples, formica, contact cement, motor mounting hardware

Introduction:

With the increasing price of commercial black powder, many pyro hobbyists are trying their hand at making their own. The process is pretty straight forward: mill some good quality meal powder, perhaps using some home-made hardwood charcoal, then compress it into hard pucks and break them apart. Screen the crushed particles into the various sizes you want and there you have it.

Most pyros already have a ball mill and various screens. Hydraulic presses are readily available on the market or easily made. However, it is the process of breaking up the pressed chunks of powder, known in the trade as "corning," which results in the most tedious labor when making home brew black powder. The simplest and probably most common method for corning is to take the chunks and break them apart using the end of a wooden bat or some other blunt, non-metallic object. However, this method is time consuming and a little nerve racking for some. Even though black powder is very stable with regard to friction and impact, the corning operation is still the source of most accidents in commercial manufacture.

Corning BP by hand also results in more work, since the grains must be repeatedly screened during the process to keep from crushing the grains that are already the desired size. Without frequent screening there will be an overly large amount of "corning dust," which is the name given to the fine grains leftover after corning. Corning dust is too fine to be used for any kind of lift or break charge, yet too grainy to be used as meal powder. While corning dust has some good uses such as dusting over prime slurry or freshly made black match, the amount resulting from any corning operation is optimally minimized.

The two most common approaches to corning involve either impact or a grinding action. Some hobbyists feed large chunks into a set of parallel grinding rollers that have pyramid shaped teeth on them. The rollers are geared to roll in opposing directions toward each other, thus grabbing the chunks and pulling them in as they are ground. This method reduces corning dust and time spent screening, but is still a manual operation conducted at close proximity.

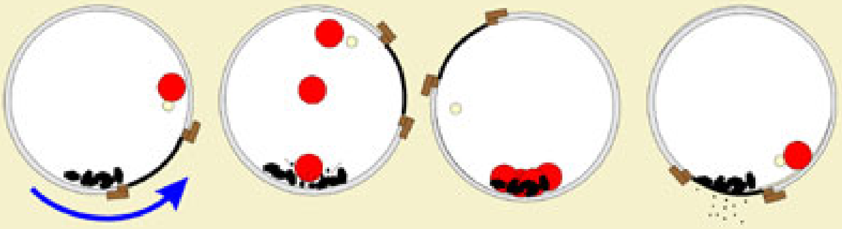

Figure 2: Corning and screening cycle for one full revolution.

The ideal corning machine should operate unattended, produce a minimal amount of corning dust and output a variety of grains that need no further grinding. The machine I have designed here does just this, and can process about a pound every fifteen minutes. The machine, shown in Figure 1, operates like a large ball mill with a screen built into the side. Each revolution of the large drum results in an impact stroke and a screening stroke.

As seen in Figure 2, the low RPM corning drum contains a single lift bar and a half dozen or so grinding balls such as billiard balls or something similar in size and weight. The lift bar catches the balls and carries them to the top of the drum, at which time they free fall to the bottom and strike the powder grains that remain at the bottom of the drum. The lift bar then comes back around and collects the balls while letting the powder grains pass between them. The powder then passes over the screen port, which removes any grains that have been reduced to the correct size. Because small grains are removed as they are produced, only the larger grains that still need to be reduced are subject to further impacts.

This impact/screen cycle results in faster corning with less corning dust while also freeing up the operator to do something else with his time. I find that this machine can corn powder at about the same rate that I can press it, so I will let the machine work on one 1000 gram batch of pressed chunks while I prepare the next 1000 gram batch.

The catch box built around the rollers also make an excellent area for screening the finished product, since there is plenty of room to vigorously shake the screens and the chute makes collecting the results easy. I place a table under the mouth of the chute so that the grains can be swept out onto a sheet of poster board for easy transfer into screens, containers or wherever it needs to go.

The remainder of this article describes how to build the machine shown above. A future article will describe the entire process for using this machine in conjunction with a ball mill and a press for making commercial quality black powder.

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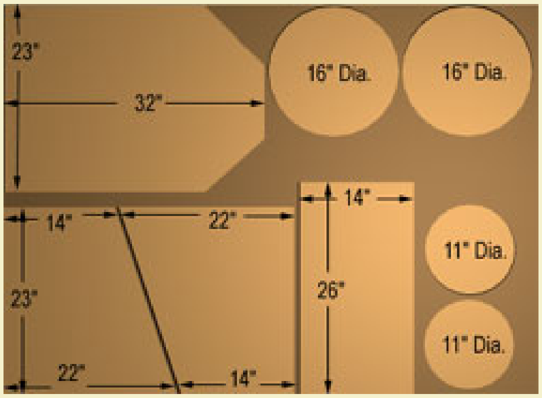

Figure 3: Cutsheet for 3/4" plywood pieces.

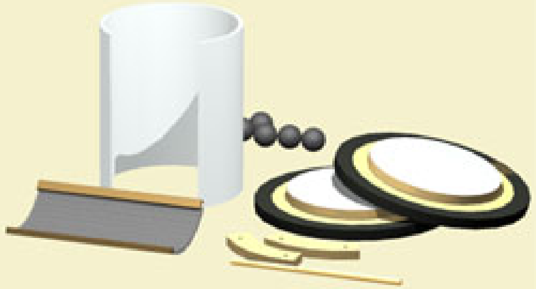

Figure 4: Components for building the corning drum.

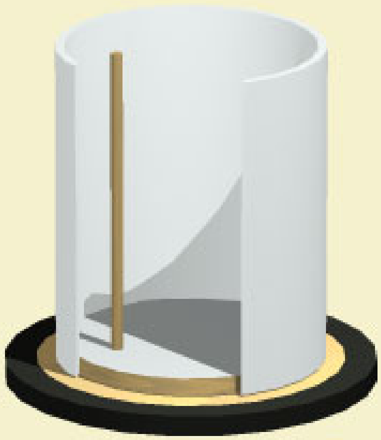

Figure 5: Single 1/2" lift bar located 2" from

The Corning Drum:

The corning machine consists of two major components: the corning drum and the roller stand (similar to a milling jar and the mill). Figure 3 shows the dimensions for the plywood pieces required for both the drum and the stand, which are cut from 3/4" thick plywood. The two 11" diameter disks need to be laminated on one side with sheets of Formica to protect the wood and provide a wear resistant surface. The large 32x23 piece, which will be the bottom of the chute that guides the powder away as it is corned, also needs to be laminated on one side with Formica so that the powder can slide easily across it.

The most difficult part to locate when building this project is a suitable piece of pipe to use for the rolling drum. The dimension of the drum will determine a lot of other dimensions, so what you wind up using may change many of the dimensions shown here. The dimensions shown here are for an 11" diameter drum that is 14" long with 1/4" thick walls. The stand will work for a range of diameters up to about 16" diameter, but the width is set specifically for a drum that is 14" long plus an extra 1.5" added by the end disks, giving a total drum width capacity of 15.5".

The corning drum must be pretty large in diameter in order to give the pool balls plenty of distance to pick up speed when they are falling. The drum must also be resistant to wear and provide a sturdy surface to pound against. The ideal material would be a segment of 16" diameter thick walled PVC, which I just happen to have recently obtained from a fellow pyro to use for this purpose. The thicker the tube wall is, the less it will absorb impact and the more effective the corning action will be.

Since 16" diameter PVC is not an easy thing to come by, the machine shown here was made using a segment of 11" diameter cardboard tube which can be purchased in some home improvement stores. These are used as forms when pouring concrete columns and are available in a variety of different sizes, although they are surprisingly expensive. They are spiral wound with about a 1/4" thick wall.

First make the two ends of the drum, which are created by gluing the 11" disk centered over the 16" diameter disk. Since it is hard to clamp these together, it is best to use screws in addition to the wood glue. If you wait to laminate the smaller inside disk after the two have been glued together, you can use the laminate to hide the screw heads.

drum wall.

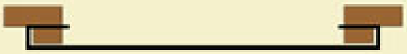

Figure 6: Edge view of screen frame assembly.

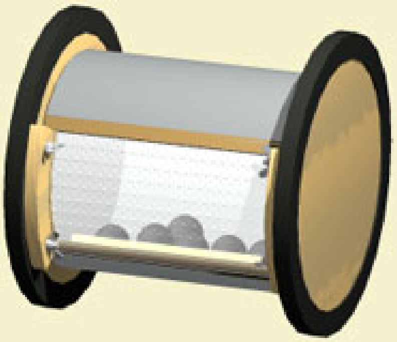

Figure 7: Completed corning drum.

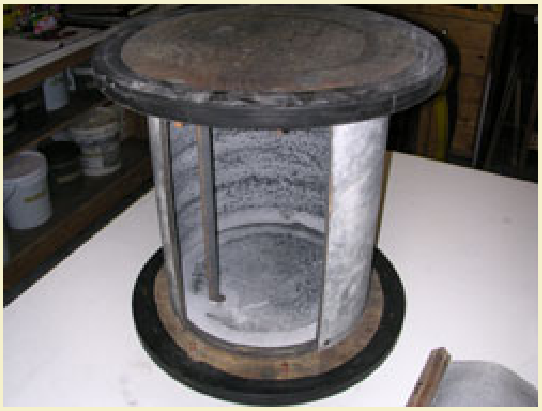

Figure 8: A corning drum after several years usage.

After the end disks are glued together, line the outside edges with rubber strips cut from a bicycle innertube. This rubber edge will serve to reduce wear on the rollers and produce better traction. The innertube is split down the side and then stapled from both sides while pulling it tight around the edge of the 16" disks. Figure 4 shows the two end disks completed. Before installing these, you will need to drill a 1/2" diameter hole measured 2" from the edge of the inner disk to the center of the hole. These holes are used to hold the lift rod and should be 3/4" deep.

Note that the location of the lift bar is critical to proper operation of this machine. The lift bar must be positioned so that the balls are released prior to reaching the peak height of rotation. This is because the optimal landing point of the balls is dead center on the bottom of the drum, but the forward velocity of the balls resulting from the speed of rotation means that they must be dropped early in order to account for their forward arc. Thus the lift bar location is subject to change based on the size of your corning balls and the speed of drum rotation. The 2" mark given here is specifically for billiard balls used in a drum rotating at 16 RPMs.

Since the cardboard tube used here is not as rigid as PVC or other materials, a corning machine made with this type of drum will not be able to break fully dried powder chunks. But it will work just fine if you corn your chunks right after pressing them when they are still slightly damp but dry enough to snap with a crisp crack when broke apart by hand. If your pressed pucks do not break with crisp sharp edges after pressing, you are not pressing them hard enough or long enough.

Because the cardboard will not hold up well to friction and does not provide a solid surface to pound against, the inside of the tube must be lined with Formica. This can be a bit of a challenge, but it is easiest to do if you remove the segment of wall where the screen will be installed first. Mark two points on the rim of the tube such that a straight line between them measures 7-1/2", then draw guide lines down the side of the tube for cutting with a hand saw or utility knife.

Once the screen slot is cut from the tube wall, fasten the tube to one of the end disks using screws around the edges. This will help hold the tube in place while applying the Formica inside. Make sure the hole in the end disk is located just behind one edge of the screen slot as shown in Figure 5.

The Formica is cut to size and trial fitted before applying any contact cement, then the inside of the tube and back side of the Formica are coated with contact cement. After about 15 minutes when the cement is dry, the Formica piece is carefully rolled up and placed into the center of the tube without touching any part of it. Make contact with the tube wall at one point and then uncoil the Formica slowly from that point outward on both sides. Any excess around the screen slot should be trimmed.

The 14" long lift bar is now inserted into the hole and the other end disk is put in place. The lift bar need not be glued, which will allow you to replace parts easily later on.

The screen that slides over the side port is made by clamping two edges of a 10" x 14" long piece of strong screen between two 1/4" hardwood slats on both sides, as seen in Figure 6. The slats are screwed together so that the overhang faces inward from the edges of the screen, then they are folded over so that the screen passes over the bottom of each piece as seen in Figure 6. This allows the screen to sit flush with the inside of the drum and prevent powder from getting hung up at the junction between the drum wall and the screen.

The screen is held in place by two wooden blocks at each end. These blocks are cut with an 11" radius where they will bind the screen against the end disks of the drum as seen in Figure 10. They are held in place by two bolts that are countersunk from the outside edge of the support disks and held on with wing nuts for easy removal. The bolts should be positioned so that the screen frame pieces can slide under them without the need for removing the bolts, since the screen will need to be slid open every time the drum is loaded. Note that all metal hardware should be stainless steel, not only to eliminate spark risks but also to avoid corrosion caused by nitrates or damp outdoor air.

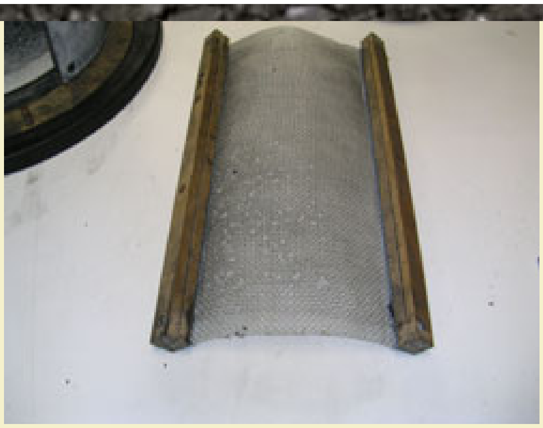
Figure 9: Interchangable screen design.

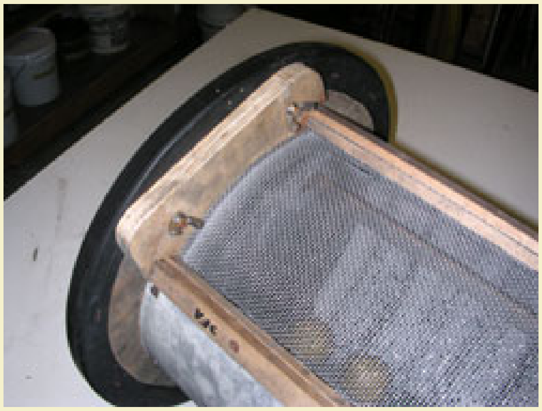
Figure 10: Closeup of screen clamp block.

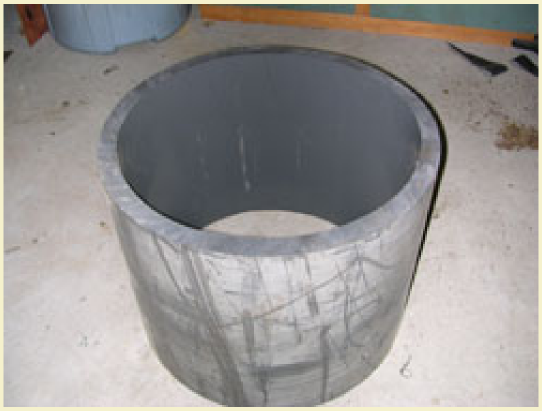
Figure 11: 16" diameter PVC with 1" thick walls for ideal corning drum.

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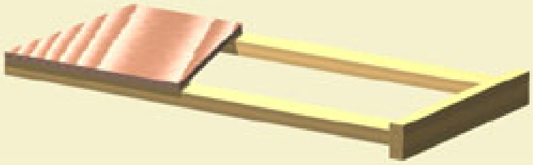

Figure 12: Assembling side panels flat on the ground.

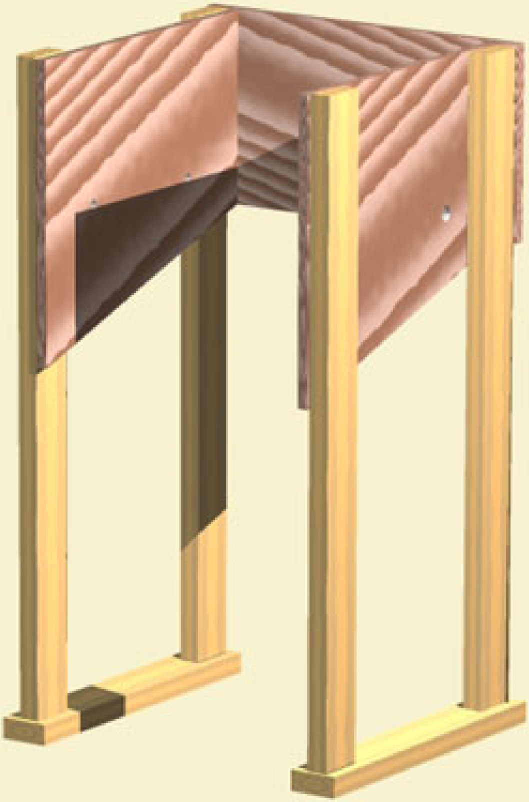

Figure 13: Side panels fastened together with the back panel.

The Rolling Stand:
The roller stand shown here is simply a box built around a set of rollers where the corning drum will spin. The bottom of the box is angled downward so that the grains that fall from the corning drum can be carried away from the under the drum.

Start by cutting out all the plywood pieces, then locate the two side pieces and mark where the holes for the rollers will be drilled. These will be 12" down from the top and 5" from the edge of each side. Start by drilling a countersunk hole half way through the plywood on the outside of each panel. The diameter of this hole should be equal to the outside diameter of the ball bearings you have. You will most likely need to use an adjustable hole cutter to make this hole a snug fit with your bearings, then use a chisel to carve out the center that the hole cutter leaves behind.

Stamped bearings are ideal for press fitting into this hole, since the outer flange around the edge of the bearing will keep it from getting pulled through the hole. If using this type of bearing, you can actually drill the large hole all the way through the plywood. Otherwise you can drill the remainder of the hole with a 1" dia. bit, which should produce a hole large enough for the rubber heater hose to fit through.

Once the side panels are cut and drilled, cut four 4 foot long 2x4s to use as the leg supports for the stand. Align two legs at each edge of the side panels and screw through the side panel into the legs while the assembly is flat on the floor as seen in Figure 12. Be sure that you don't create two left or right sides, as one should mirror the other.

A 2 foot long 2x4 foot is now fastened to the bottom of the legs on each side assembly, as seen in Figure 12. This is done using the 1/4" lag screws, which must be countersunk so that the wood sits flat on the floor.

The side pieces are now stood upright and the back panel is clamped in place and screwed into the 2x4s as shown in Figure 13. Note that the back panel should extend all the way to the outside edges of the 2x4 legs.

Once the back panel is secure, flip the unit upside down and align the bottom panel. This panel should be laminated on one side with Formica prior to assembly. The Formica will provide a smooth surface for the powder to slide across, as well as make the surface easier to clean. It may be easier to cut the angled front corners after the panel is test fitted in place so that you can mark the exact point where the overhang meets the side walls.

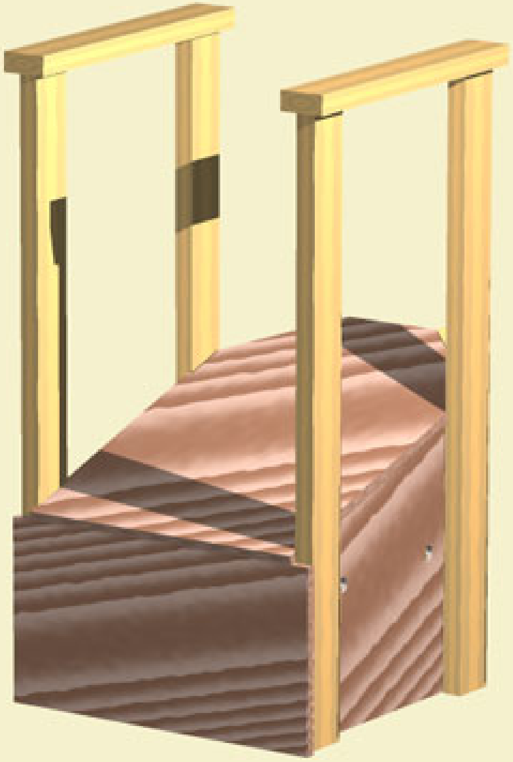

Figure 14: Inverting the corning stand to fasten the bottom panel.

Once the bottom panel is fully fabricated, attach it to the bottom by screwing around the perimeter into the edge of the plywood side pieces.

The unit is now turned upright again and the hardware components are installed. The 5/8" ID heater hose pieces are slipped over the steel roller bars, then the bars are passed through the holes in the side walls. The bearings are slipped over the ends and then press fit into the side panels. The bars are now kept from sliding out of place by securing shaft collars on both ends. Note that the longer bar goes in the back set of holes, and the extra length is applied to the right side where the drive pulley will be attached. The 8" drive pulley should be installed to make sure it does not rub against the support legs at this point.

A single 2" dia. swivel caster is fastened at the center point between the two roller bars at the top edge of each side. These are used to prevent the drum from traveling to either side and rubbing against the side walls during operation.

The angled edges of the chute are faced off with pieces of wood as seen in Figure 15. These are screwed into the edge of the chute panel and serve to guide the powder out the front of the unit.

Lastly you are ready to attach the drive motor to the unit. A cross bar is first screwed into place 8" down from the bottom edge of the back panel using two 1/4" lag screws on each side, as seen in Figure 16. The motor is bolted onto a plywood plate that is then mounted to this cross piece using hinges as shown. A 2" pulley is fastened to the drive shaft and aligned with the 8" pulley above it.

The motor used here is a 1/2 H.P. AC motor with built in starting capacitor and runs at 1145 RPMs. The rotation speed of the drum is not real critical as is the case with ball mills. If built exactly as shown here, the drum will rotate at about 16 RPMs. The speed could be increase a little, but rotating the drum too quickly will tend to throw the balls too far forward and they will miss their target at the bottom of the drum. There are no problems with lower speeds other than less efficient milling times.

Usage Notes:
The drum should be placed on the roller so that the lift bar always rolls ahead of the screen panel. If the drum rolls clockwise looking from the right side, then the lift bar should be to the back of the machine when the screen is in the loading position, otherwise the lift bar should be at the front. The basic idea is to make sure that the grinding balls do not roll over the screen during operation.

Note that the screens can be easily changed to produce different sized powder grains. The screen represents the largest size grain that is desired, since there will always be many grains smaller than the screen size that will be produced. However, using smaller screens such as 40 mesh in an attempt to produce only 4Fg size powder will result in a higher percentage of corning dust.

With a 15 mesh screen, this machine will yield about 40% 3FA, 35%

4Fg and 25% corning dust. These percentages will vary depending on how well you pressed your powder cakes before putting them into the machine. Overly damp or crumbly cakes will naturally result in a higher percentage of corning dust.

I like to break the pressed powder cakes into large pieces by hand before placing them into the machine, otherwise they may get stuck or ride the lift bar up with the drop balls. Much of the powder gets carried up and dropped with the pool balls anyway, so pre-cracking the cakes may not really be necessary. From the sound of the machine, it appears that the powder that gets carried up is the first to fall from the top of the drum, then the pool balls come crashing down shortly after.

Figure 17 shows an attempt to automate the screening process so that it occurs during milling. A second pulley was added to the side and powered from the drive roller. An off-center arm is connected from this wheel to a box of stacked screens mounted on a swivel cradle such that each rotation of the wheel rocks the cradle back and forth. The idea was for the powder to fall down into this continuously rocking box of screens, which were stacked in order from most coarse to least, and the grains would be shaken down to settle on the various screens. However, much of the powder tends to collect on the chute into a big clump that slowly slides down into the screen all at once. The rocking action provided by this setup was not adequate for getting the powder to settle out, so it tended to just collect in a big pile on the first screen. A much more aggressive shaking motion would be required for something like this to work, so I eliminated this part of the design and just do the screening by hand.

This machine is really no more difficult to build than a ball mill, and the work it will save you is well worth the work required to build it.

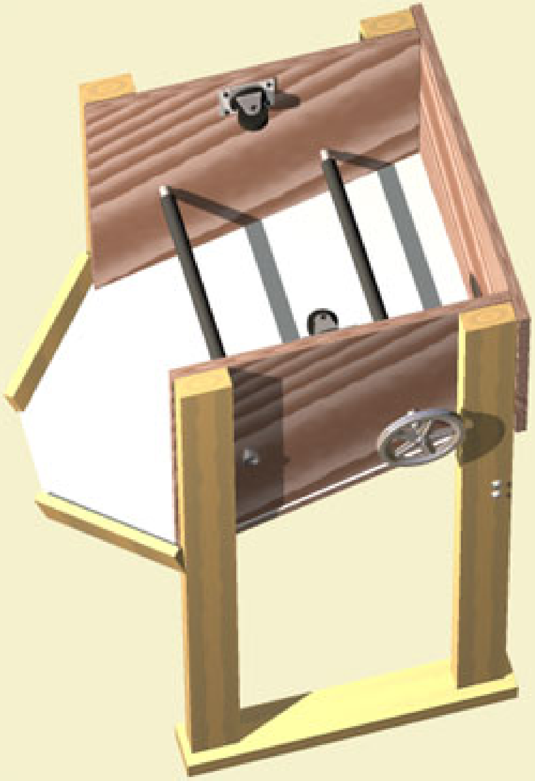

Figure 15: Installing roller bars and casters.

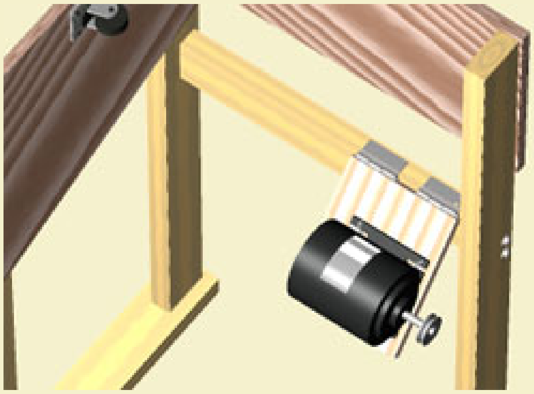

Figure 16: Installing the motor using a hinged plate.

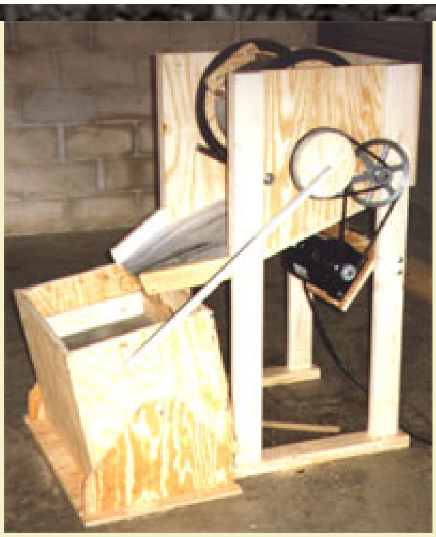

Figure 17: Variation using rocking screen stack to sort grains while corning.

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Tool Tip... **Page 1**

Making a Cross Match Punch

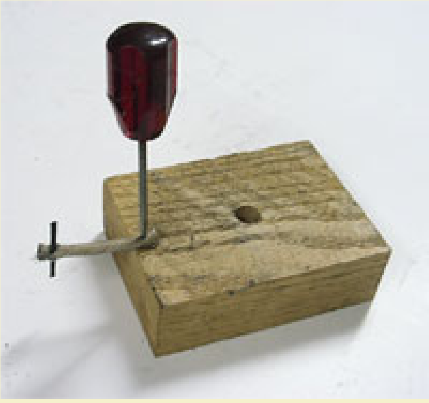

Figure 1: Using an awl to manually punch time fuse.

Introduction:
One of the most reliable ways to insure ignition of commercial time fuse is to punch a hole through it and insert a short stick of black match. This process, known as "cross matching," provides two paths of ignition and has proven itself very reliable. The thin piece of black match takes fire much more readily than if the time fuse were merely dipped in slurry prime. Not only is the ability to take fire superior, this method is quick and requires no drying time. The time fuse can be matched and then immediately put to use.

The first obstacle with this method, however, is finding an easy way to make the small hole through the piece of time fuse. The three most commonly used methods of achieving this task are presented here in order of increasing complexity.

Method 1:
The most primitive method of punching the time fuse hole involves the use of an awl to manually drive a hole through the fuse. The fuse is first cut to size, then marked where the holes are to be punched. The holes are usually punched at least 1/4" from each end of the time fuse. Making the hole any closer to the end of the fuse will often result in splitting the end of the fuse open.

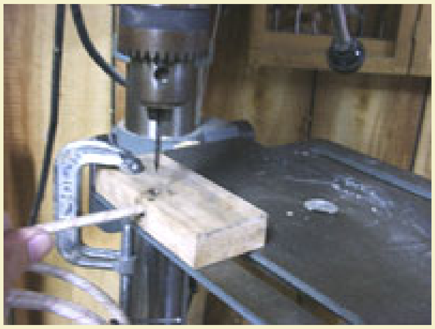

Figure 2: A simple jig that utilizes a drill press as the punching mechanism.

The awl should be at least 1/8" diameter so that the black match will fit through the resulting hole. A block of wood with a hole slightly larger than the awl diameter drilled near it's edge allows the time fuse to be supported while allowing the awl to pass through the time fuse.

Since the powder core of commercial time fuse is surrounded by a water resistant layer of tar pitch, some believe that twisting the awl when piercing the fuse can result in smearing the tar and blocking the powder train. I find that it is difficult to pierce the fuse without twisting the awl back and forth at least slightly, and have never had ignition blockage problems.

Method 2:
While the awl method works, it quickly becomes tiresome if you have many fuses to make. A drill press can easily be converted to a cross match punch using a simple block of wood clamped to the drill stand. The wood should contain a hole slightly larger than the diameter of the time fuse to be punched (I use a 9/32" hole), drilled into the edge of the block to a depth of about 5/8". This hole is then intersected by a smaller hole that is slightly larger than the diameter of the tapered rod that will be used to punch the hole (I use a 9/64" hole). The small hole should be located at least 1/4" from the end of the larger hole and run all the way through the block of wood.

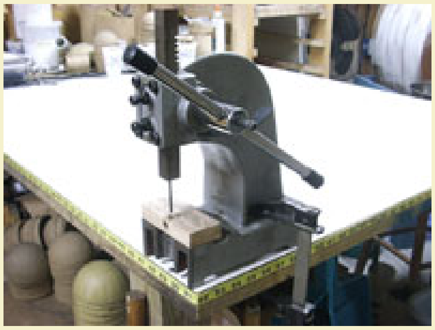

Figure 3: A dedicated cross match

A metal rod of at least 1/8" diameter is then sharpened on a grinder and punch made using a small arbor press.

inserted into the drill chuck. The diameter of the rod you use will be dictated by the diameter of your cross match. It is possible to punch the hole with a flat-ended rod, but I prefer to use a sharp point.

The punch block is now clamped to the drill stand so that the punch rod is centered over the small hole, as seen in Figure 2. The time fuse is simply inserted into the hole in the side of the block until it will not go in any further, then the punch is brought down using the drill press as an arbor press (with the power off). This will result in cross match holes that are consistently punched at the same distance from the end of the time fuse.

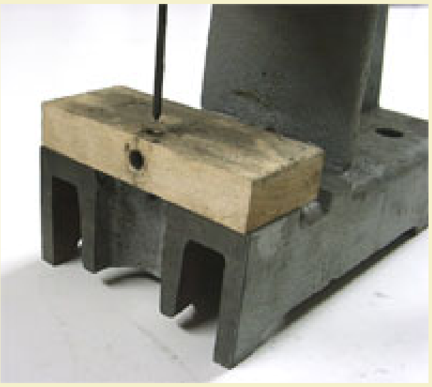

Figure 4: Closeup of the punch block.

Method 3:
If you really find yourself cross matching a lot of time fuse, it may be worth the trouble of making a dedicated cross match punch using a small arbor press, as seen in Figure 3. This press uses the same punch block as described above, except it is fastened to the base of the arbor press by screwing through the bottom with a few wood screws (see Figure 5).

The square press head must be removed from the press and fitted with a tapered punch pin. It is easiest to drill a hole in the end of the rod and press fit the punch pin using a hammer. The pin can then be sharpened on a grinder after it is in place.

It is best to install the punch pin first, then push it through the block of wood to insure alignment before the block is secured to the metal base. This way there are no surprises after the wood has been attached.

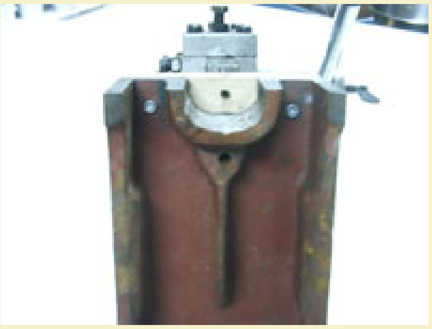

Figure 5: Punch block held to base with two wood screws through the bottom.

Since you will often be punching holes through time fuse that is already secured and pasted into a shell, it is desirable to be able to work with very short segments of time fuse. The distance between the cross punch hole and the edge of the wood block should be made as short as possible to help with this goal. Since most arbor presses have feet that will extend beyond the edge of your wood block, it may be necessary to cut them off with a hack saw (preferably a vertical power cutoff saw). Figure 4 shows a close-up of the truncated base, revealing the inner cavity of the cast iron feet.

Your lightweight and portable cross match punch can easily be clamped to your workbench when in use, as seen in Figure 3. This method eliminates the setup time and location restriction of the drill press method while also allowing you to work with short time fuses pasted into shells that would not clear the drill chuck if punched using drill press jig.

One final note about cross matching: be sure the cross match is firmly held in place after it is inserted. This can be accomplished by squeezing the junction with a pair of pliers after the match is centered. The cross match hole should only be as large as it needs to be for the match to pass through, leaving no extra space for slop. Failure to secure the cross match can result in it falling out due to the centrifugal forces of the rapidly spinning shell as it exits the mortar.

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Tool Tip...

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Crossette Productivity Tools

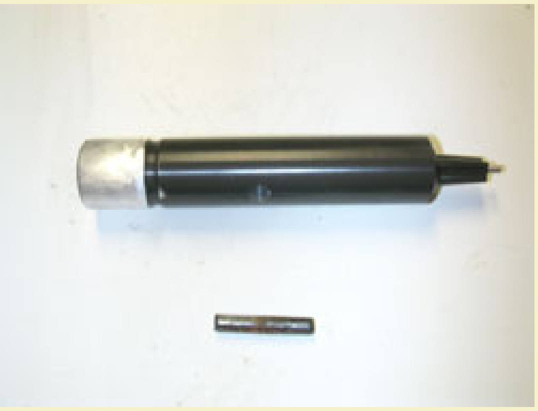

Figure 1: Removing the stop pin from a traditional 3/4" crossette pump.

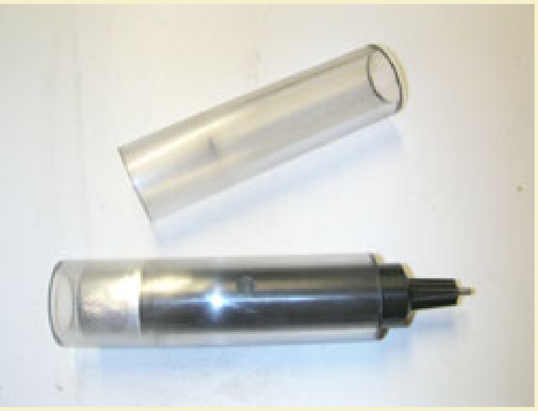

Figure 2: Knurled end is sanded down so that it slides easily through a 3/4" I.D. tube.

Introduction:

Crossettes are among the more difficult and time consuming effects to achieve with any degree of reliability. There are many variables that can be hard to control, which can throw off the timing or ruin the effect. The ideal of having hundreds of splitting comets all break into four equal sized pieces at the same exact time is indeed a difficult thing to achieve. Even when you do get the procedure for making good crossettes down, it can be a very time consuming effort when producing shells that contain hundreds of crossettes. This article, which is a companion to the Wax Dipped Crossette article, shows how to build a few handy tools that help eliminate some of the inconsistencies between crossettes as well as make the process go faster.

The two primary areas of failure in crossettes are 1) timing of the split and 2) quality of the split. Timing errors result when the comet splits too early or two late relative to the other comets. Timing errors are most commonly caused by inconsistencies in the amount of composition charged into each crossette, failure of the break charge to take fire at the proper time or wrinkles in the paste wrap that allows fire to jet down the side and short-circuit the normal burn path. Split malfunctions include excess fragmenting into many pieces instead of the desired four, pieces being blown blind, pieces not being spread far enough or complete failure of the crossette to split at all. Splitting failures are generally linked to an improper burst charge or inadequate confinement of the burst charge.

Making a Fill Plate

The first tool presented here is designed to insure that the same amount of composition is used to produce each crossette, thus avoiding timing errors that result from differences in the amount of composition between crossettes of a given batch. This tool also results in faster production compared with the standard method using a traditional crossette pump. The traditional method requires a single sleeve to be rammed into a bucket of damp comp, pressed, and then shaved off to a given length. The problem with this method is that the amount of comp pressed in the sleeve is not the same each time, since there is some randomness in how much the operator loads before pressing. Since the pressure is not typically controlled when pressing crossettes, the density of the comp will not be the same between different pressings due to the difference in the amount of comp being pressed combined with inconsistencies in the pressing force. So even though the crossettes are trimmed to the same size after pressing, there is still the potential for differences in density that can throw off the timing slightly. From a production standpoint, there is also the extra step of having to trim off the end of the crossette before ejecting it.

The multi-tube fixture described here uses the granulation method to insure that the same amount of comp is being pressed in each crossette. The method is similar to using a large star plate, except that the comets are still pumped one at a time instead of all at once. There is also a productivity gain from loading many pressing sleeves at once, similar to how other items such as rockets or whistles can be produced faster when loading an array of tubes instead of one at a time. The trimming step is eliminated, resulting in faster production and nice flat bottom surfaces on the completed crossettes. Note that this same fixture can also be used to produce regular comets as well.

The crossette pump used here was made by Wolter Pyro Tools and is the square cavity type that leaves a pin hole at the bottom. Cheaper pumps can be found that produce a round cavity, but crossettes made with these don't break into four pieces as reliably.

Standard crossette pumps have a stop-pin drilled into the side, which must be removed as shown in Figure 1. The pin can be clamped in a bench vice and then the rammer is rotated while pulling on it until the pin can be worked out. Wolter's pumps also have a knurled knob at the end, which unfortunately prevents the entire pump from sliding all the way through a 3/4" I.D. tube. The knurl must be sanded down until the point where it will easily slide through the tube as seen in Figure 2.

The tubes used here are polycarbonate hollow rod purchased from McMaster-Carr, part number 8585K35. The polycarbonate is much nicer to work with than acrylic, since it won't crack or chip, and is much stronger as well. While any type of tubing with exactly 3/4" I.D. can be used, the polycarbonate seemed to be cheaper than PVC, Delren or metal tubes. It is also kind of neat to be able to see the composition in the clear tube as you are pressing it! If these tubes are used to press compositions containing titanium then they will most likely get scratched up on the inside. I was concerned that even magnalium might scratch up the tubes, but that does not seem to be a problem. Color and charcoal compositions will of course not be a problem, although acetone bound mixtures can not be used with the plastic tubes.

A tube count of 16 is used so that the jig size is manageable and also so that you don't have so many tubes to clean up afterwards. Larger array sizes would make it increasingly difficult to slide the retainer board from top to bottom of all the tubes after they are loaded, but the four by four array is no problem.

The length of the tubes were determined by experimentation using the most compressible composition I plan to use for crossettes, which is a 50% charcoal streamer type mix. The tube length will control how much delay there is before the crossette breaks, which is a variable the also depends on the size shell any given crossette will be used in. The tubes shown here were cut to 3-5/8" length, although you might want to go to 3-3/4" if you want to make charcoal

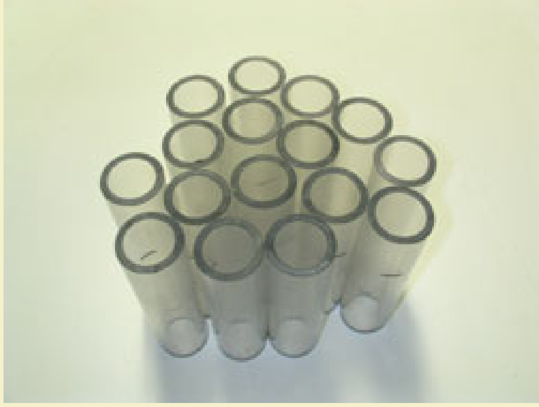

Figure 3: Sixteen polycarbonate tubes are cut to exactly the same height.

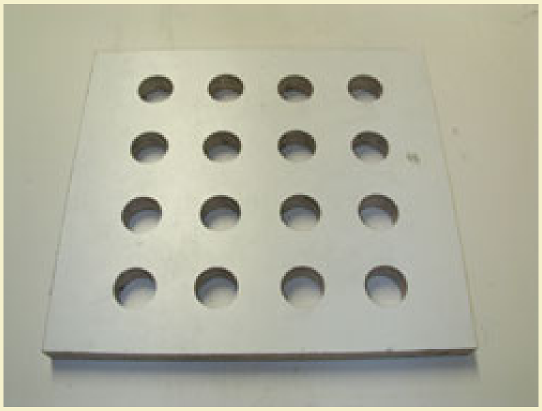

Figure 4: A four by four array of 1" dia. holes drilled in a piece of plastic coated shelving board.

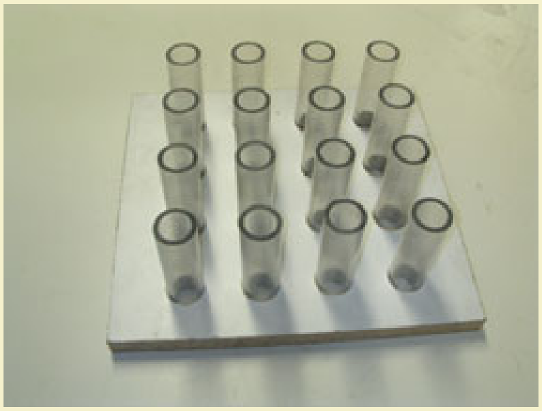

Figure 5: The tubes inserted into the holes should fit snugly.

crossettes for six inch shells. The best approach would really be to cut a 4" long tube and then have a set of pin plates with different size nipples that control the fill height inside the tube. Since it is easier and cheaper to make a wooden plate with dowel rods glued into for various crossette types it than it is to cut a set of tubes for each type (especially considering the polycarb tube costs $30 with $24 to ship it).

Next you will need to make a hole plate for holding the tubes. The plate provides a working surface when filling the tubes, after which it is pushed down out of the way so that the tubes can be removed. I used a piece of white plastic coated shelving board commonly available in hardware stores, since it provides a smooth washable surface that won't get stained by damp powder. A set of 1" diameter holes are spaced on 2" centers with a 2" border around the outside of the holes so that composition won't drop off the edge while you are filling them. Figure 4 shows the completed hole plate, while Figure 5 shows the plate with the tubes inserted.

It might be possible to use the jig with just the tubes and the hole plate if the tubes fit snug enough. However, I use a frame for the board to rest on while loading the tubes just in case. Over time the tubes may become looser and the board could slide down during the loading process if there is nothing supporting it from below. The frame height should be cut so that when placed under the hole plate, the edge of the tubes sit flush with the top surface of the hole plate. This will vary depending on your tube length and hole plate thickness, but 3" was the height used for mine. The frame shown in Figure 6 is constructed with one end open so that the frame can be slid out from under the tube assembly after it is loaded. Really this could be simplified to just two pieces of wood used to prop up each side of the frame during loading- it doesn't need to be a whole frame as shown. Originally I was going to attach a platform to the closed section of the frame and build walls around the edges, with the idea being to pile powder on the platform and then drag it across all the tubes as a faster way of filling them. See the crossette loader tool in the next section to get an idea of how that would work.

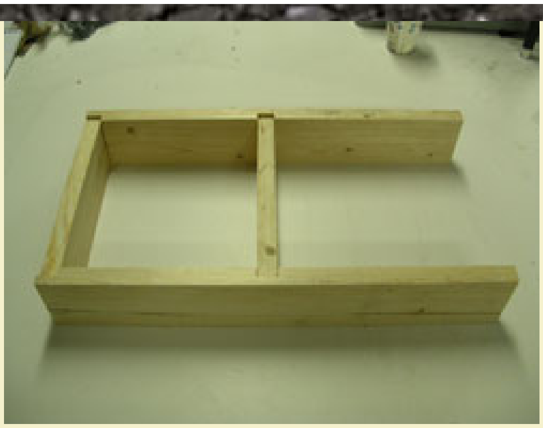
Figure 6: An open ended frame to support the board while loading composition.

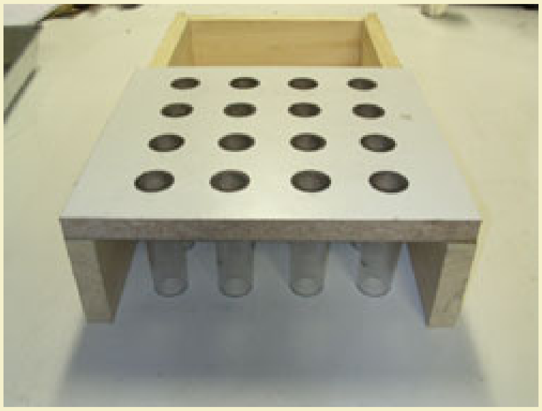
Figure 7: The tube array in place on top of the support frame.

The last item you will need to finish off this tool is a small nipple to insert the tube onto when pressing the crossettes. Figure 8 shows a scrap of maple with a 3/4" aluminum rod running through it so that only about 1/8" sticks up. The purpose of this nipple is to avoid pressing powder right up to the end of the tube, which will result in powder squeezing out beyond the edges at the bottom of the tube. This powder flange would then need to be trimmed off with a knife, adding an extra step to the process that is easily avoided by just pressing on top of the base shown. Figure 9 shows how the wood was trimmed to allow it to fit into the channel of my particular arbor press.

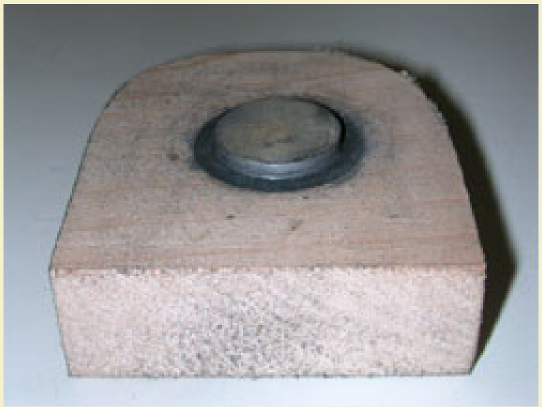
Figure 8: A small nipple is used at the base of the tubes when pressing.

While you can hand ram the pressing step using a rubber mallet, an arbor press of at least two ton capacity make the pressing go much faster and quieter. An arbor press also makes it easier to regulate the height of the pressed comet, since all you need to do is make a reference mark on the piston bar and press to the mark for each comet.

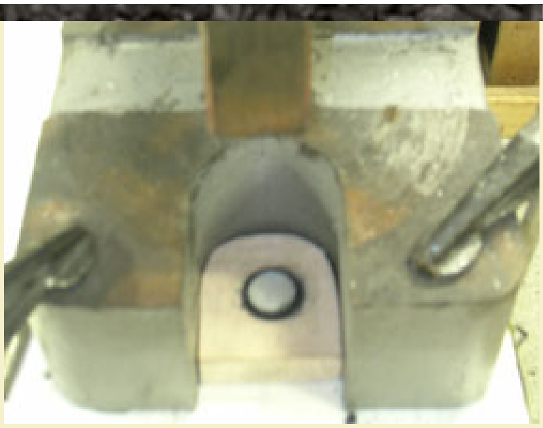

Figure 9: The base is rounded off to allow it to fit inside the arbor press cavity.

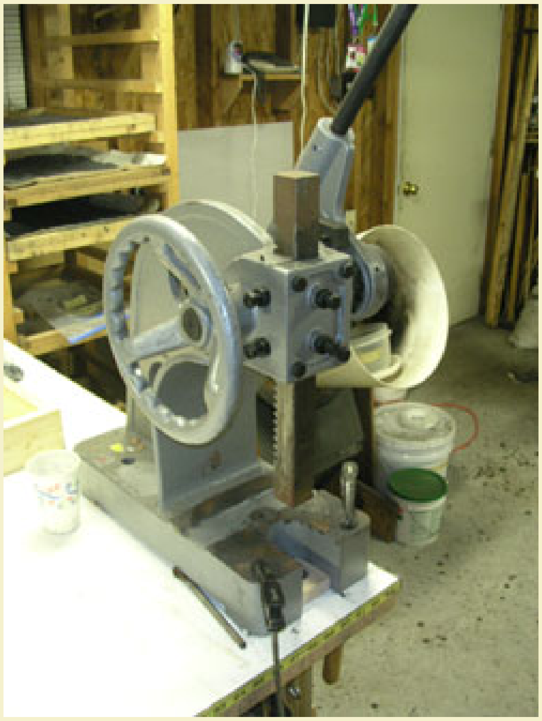

Figure 10: A ratchet type arbor press for easy pulling action.

The arbor press shown in Figure 10 is a ratchet type, which are a little more expensive than the standard ones but worth the extra money. The wheel on the left side is used to bring the rammer down on the work piece quickly, then the lever engages a ratchet so that you are always pulling from a position of maximum leverage. When pressing hundreds of crossettes in one sitting, any little bit of extra comfort can save a lot of time and fatigue.

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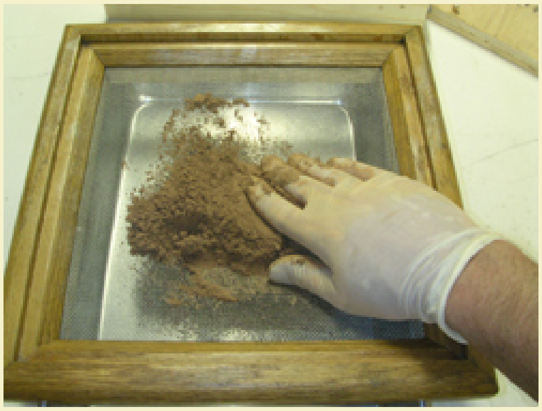

Figure 11: Granulating damp composition through a window screen.

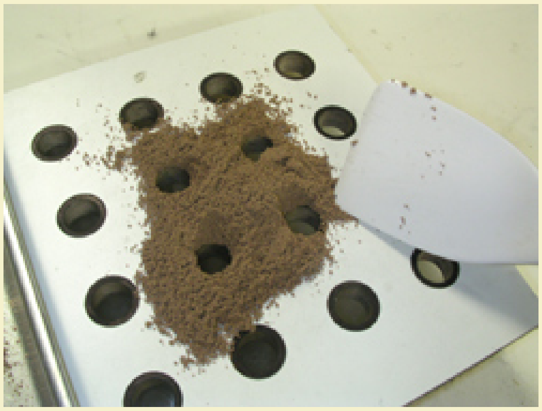

Figure 12: Filling tube array with granulated composition.

Using the Fill Plate:
To use the fill plate, you must first granulate your composition into a free-flowing state so that it can be used to fill the tubes. This is done by dampening the composition with the required binder and then pushing it through a window screen as seen in Figure 11. When using plastic tubes to pump the comets in, only water or alcohol solutions can be used, as other solvents may damage the tubes.

The percentage of solution to use when dampening the powder will vary for each type of composition. When damp, the powder should be able to pass through a screen without clogging up the holes, and the resulting granules should not easily stick to each other or clumping will result. There is no concern for under-wetting the powder, only over-wetting can cause problems. The amount of solution required for making pumped comets generally works fine for the granulation step as well. Some common percentages are 15% for charcoal streamers that have 50% or more charcoal by weight, 20% for color compositions that have a lot of parlon and tend to be crumbly when wet and 10% for glitters and organic color compositions. A general rule is that you should be able to pump your comet without squeezing any water out of it. If water seeps out of either end, then the composition was too wet.

After granulation, the composition is scooped onto the surface of the loading plate, as seen in Figure 12. A piece of stiff cardboard or a spatula helps spread the pile around so that it falls into the holes and fills them. Because the holes are so deep, you can't really fill them all in one pass by scooping one large pile of powder over them because the powder pile would have to be about three inches high. If you were making large batches then you could build walls on each side of the hole plate and try the one-pass method, but most people will probably find it easier to just shovel the powder onto the plate as needed and shift it around until all the holes are filled.

Once the holes are filled, the excess powder is scrapped off one edge into a catch pan and returned to the holding container. Every tube should be filled level with the surface of the hole plate, as seen in Figure 13.

Once loaded, the support frame is removed from under the hole plate and the plate is then pushed down flat against the table surface as seen in Figure 14. The tubes are now easily removed one at a time for pumping. The crossette pump is first pressed into the tube while it is still in the hole plate and the composition is compressed by hand so that it will not spill out when the tube is removed. The tube is then removed and placed on the ramming

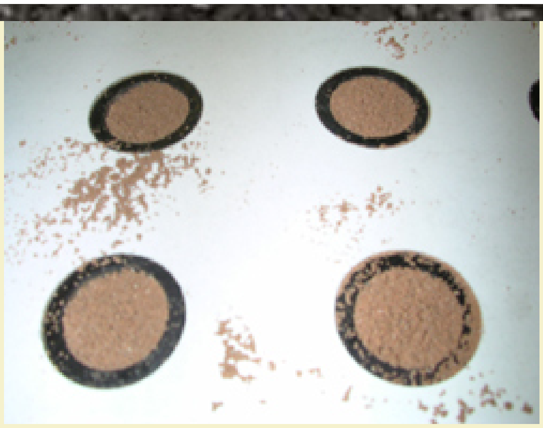

Figure 13: Tubes are filled to the top and leveled off with a scraper.

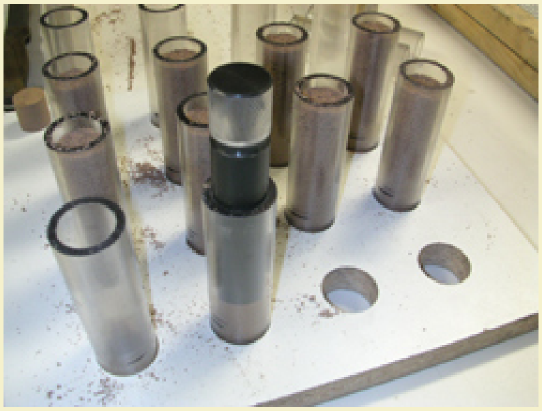

Figure 14: Loading board is pushed down to allow easy removal of the loaded tubes.

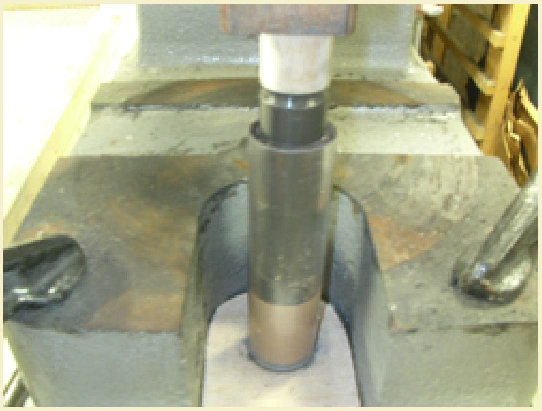

Figure 15: Pressing a crossette in the arbor press.

nipple as seen in Figure 15. An arbor press is the best way to get both speed and consistency in pressing the comets, but a rubber mallet can be used as well. When using a mallet, you might want to make a mark on each tube that serves as a visual aid for when the composition has been compressed to the desired height.

Once pressed, the tube is removed from the nipple with a twisting motion to ensure that no composition will get stuck to the nipple surface. Before pressing the comet out of the tube, it is important to first pull the crossette pump out of the comet and then reinsert it back in place in order to help loosen the hold the comet will have on the pump. If you skip this step and just try to pull the comet off the end of the pump after it has been ejected from the tube, you will more than likely crush the comet with your fingers in the process. By extracting the pump will the comet is still protected by the tube walls, it will be much easier to pull it off once ejected. Just be careful not to rotate the pump while pulling it or your will damage the delicate cross shape of the burst cavity. You will need to re-insert it back into the cavity exactly as it originally was in order to prevent damage.

At this point the pump is inverted onto a table so that the tube can be pushed down around the pump in order to eject the comet. If you find that it takes a lot of effort to eject the comet, then you are pressing them with too much force. The comet should entirely clear the tube before carefully removing it from the end of the pump. Extreme care must be taken not to pinch the comet too hard between your fingers while pulling it or you will crush the fragile walls of the burst cavity.

You may find that bits of composition will stick around the base of the burst cavity former on the crossette pump, with matching chips missing from the top of the crossettes. This sticking problem is quite common and can be annoying to deal with. I find the best way to avoid it is to spray the tip of the crossette pump with WD-40 and then wipe it down to remove the oil. This will prevent sticking for at least four crossettes before having to do it again, depending on how sticky your composition is. It's an extra step in the process, but not as time consuming as removing the caked up composition off your crossette pump after each comet that is pressed!

Once all the tubes have been pressed, the hole plate is inverted and the tubes are placed back in their spots. I prefer to place the empty tubes back into the holes after pumping each one, then inverting the hole setup and pushing the hole plate back down to the table to reset the board into the loading configuration.

My timed tests show that, including the granulation step, I can pump about 70 crossettes per hour using this setup. With more practice I could probably get that number even higher, but that's somewhere around what a beginner might expect to see after going through the process a few times.

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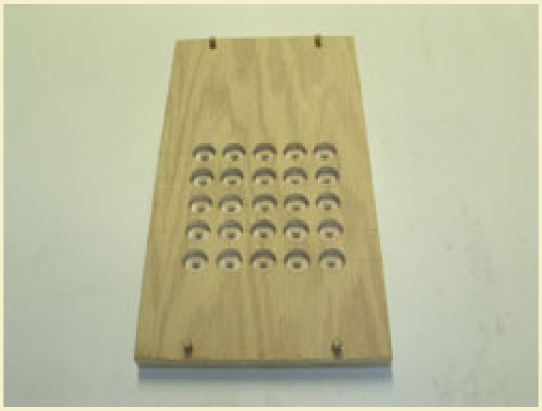

Figure 16: A five by five array of holes drilled 1/4" deep into the base board.

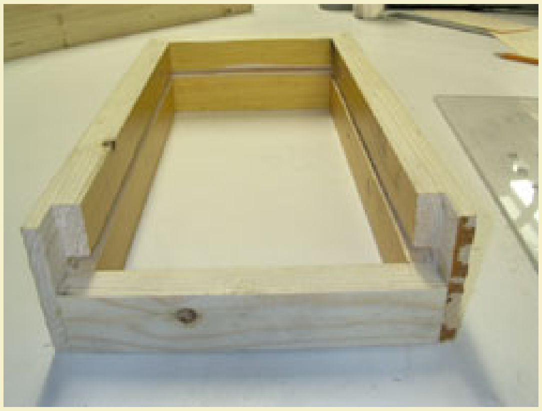

Figure 17: The box frame with a double track that holds both the hole board and a sliding sheet of formica.

Making a BP Charge Loader:
The key word here is "BP", as this tool should not be used to load other types of burst charge into crossettes due to friction concerns. Because there are sliding parts where trapped powder grains can be subjected to friction and grinding, it should not be used with granulated flash, granulated whistle or anything other than black powder grains.

Since black powder is generally not strong enough to break crossettes, you may be asking what use could there be for this tool? Well, one very effective burst charge for crossettes is small grain black powder combined with flash powder. This charge takes fire easier, does not cause the "jetting" problem, makes it difficult to accidentally add too much flash and it also avoids the white flash of light that typically ruins most charcoal crossettes when broken with flash. The black powder grains are loaded first into the crossette cavity, then the remaining empty space is topped off with flash. Trying to pre-mix the BP and flash in a separate container and then add them both at once results in inconsistent BP to flash ratios that are hard to control. The most reliable method is to add a controlled amount of BP first, then fill the remaining void with flash.

The BP+flash charge also makes it easier to fine tune your burst charges to get the exact type of break you need. If the crossette is breaking too hard and fragmenting or blowing the pieces blind, simply increase the BP charge, which will automatically decrease the amount of flash that can be loaded. If the breaks are too wimpy, then decrease the BP charge so that more flash will fit in the cavity. It's a pretty nice system, it's just hard to consistently add the right amount of black powder to each crossette due to the inherently small amount of charges required for 3/4" crossette cavities. That's where this tool comes in to make the job easy!

Jigs like this one are commonly used in industry to drop lift charges for cake items into many tubes at once, and of course the tool shown here could be built with different dimensions to be used for that purpose as well. The idea is to fill a series of holes designed to measure out the proper amount of charge, then pull the bottom out from all the holes at once so that the powder drops down into the desired location (crossette cavities in this case).

Construction:
There are four components to this tool: 1) the base plate 2) the frame box 3) the hole plate and 4) the sliding plate. While the primary purpose of the base plate is to hold the crossette in alignment with the hole plate, it also makes a good jig in itself for

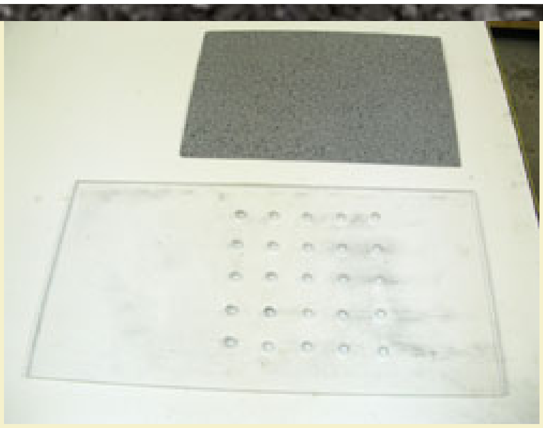

Figure 18: A 3/16" sheet of acrylic with an array of 1/4" holes that aligns with the holes in the base board.

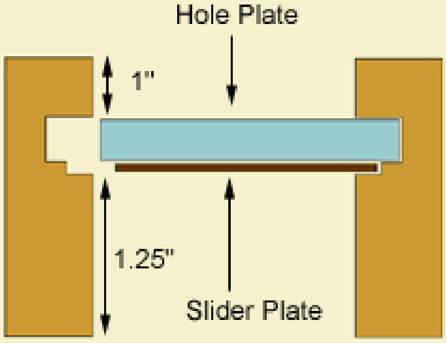

Figure 19: Slider track details.

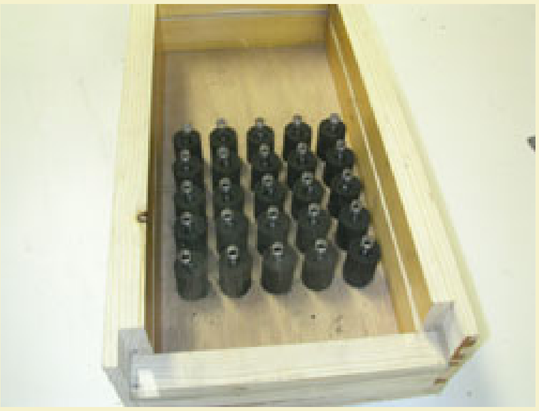

Figure 20: The box frame with hole plate is set in place above the base board loaded with crossettes.

holding crossettes during the fusing and flash loading steps. The board is 12" x 7" and holds a five by five array of crossettes on one inch centers. These dimensions are arbitrary and could be made to hold more crossettes, but twenty five seems to be a good working number.

Start by cutting a 12" x 7" piece of good quality plywood or particle board that is 3/4" thick to use as the base plate. A piece of 1x8 oak could also be used, but pine should be avoided due to its tendency to cup, warp and cause other problems.

Mark a grid at the center of the base plate such that the left and right margins are 1.5" from the edge, with 1" between each hole. A 3/4" wood drilling bit is used to countersink 25 flat bottomed holes 1/4" deep into the base plate, as seen in Figure 16. The only other step to complete the base plate is to sink four 1/4" dowel rods at each corner so that they stick up about 1/4" above the surface. These will fit into holes on the bottom of the box frame so that the frame is locked in place during use.

The box frame is the tricky part to make for this jig, since you have to cut a very accurate set of channels into the side which will hold both the hole plate and the slider plate with very little slop between them. The configuration for this sliding track is shown in Figure 19.

It is best start with a 3.5 foot long board and cut the channel into the board first before cross cutting the box walls out of the board, that way the channel will be aligned on all pieces. The 1/4" thick hole plate channel is cut first using a dado blade or router, then the thinner channel for the Formica slider plate is trimmed away using a regular saw blade or router. Adjustable dado blades are ideal since that would allow you to cut the 1/4" channel just a hair wider so that the hole plate will easily slide in place. You don't want the hole plate sloping around during use though, so this is a critical cut to get right. Be sure to practice and trial fit some 1/4" plexiglass into a test cut before making the real cut.

Once the set of slider tracks are cut, the board is then cut up into the pieces required to make a box that fits exactly onto the hole plate. I prefer rabbit joints for this type of box, but you can use butt joints, dovetails or whatever you like. Just be sure to cut the front end down below the track so that you can get the sliding plates in and out of the frame, as seen in Figure 17. The final step is to drill the 1/4" holes in the bottom of the frame so that they align with the dowel pins on the base plate. I find the easiest way to do this is to put a dab of white glue on top of each pin and then carefully set the frame on top of them so that it is aligned with the base plate. The glue will mark the points where you need to drill on the frame bottom.

Next you will need to make the hole plate. For a charge that fills my crossette cavities about 50% full, I experimentally determined that a 1/4" sheet of plexiglass with a 1/4" hole drilled in it will hold the proper amount of charge required for a 3/4" charcoal crossette that will use 70-30 flash made with American dark aluminum (809). You can see there are a lot of variables here, so you will need to get the break charges for your crossettes worked out first before even attempting to make this jig, unless you want to make the exact same

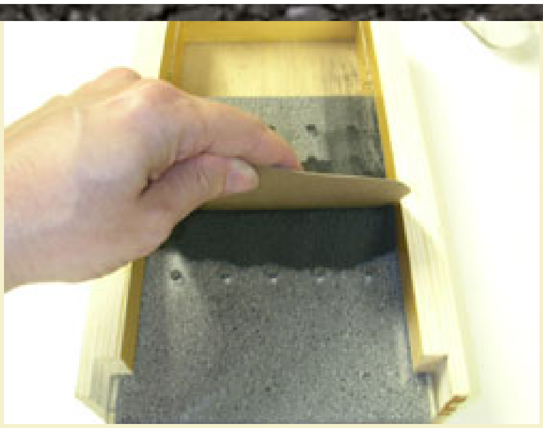

Figure 21: With formica barrier in place, a pile of 2Fg is dragged across the holes to fill them all at once.

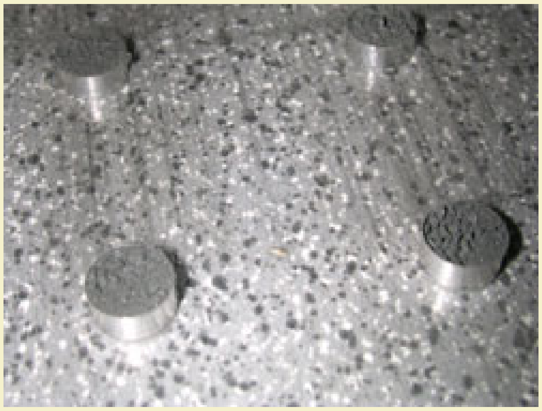

Figure 22: Close-up of 2Fg in the charge holes after scraping away the excess.

crossettes used here. If you are making color crossettes, then this burst charge is too strong and will not work. If you are using German or Indian dark aluminum, then the charge will be too strong also. Crossettes are VERY sensitive to all sorts of variables, especially these small 3/4" size ones. For an exact description of how the crossettes designed to be used with the hole plate dimensions shown here, see the Wax Dipped Crossettes article in this issue.

Use a black marker or sharp scriber to maker the center points where each hole is to be drilled. You can either measure these out or simply place the plexiglass on top of the base plate (remove dowels first) and visually mark the center points of each hole. If using acrylic plexiglass, you will need to set your drill press at around 2000 RPM in order to prevent the bit from grabbing and cracking your work piece when drilling through the sheet. Be careful not to set the RPMs too high or drill so slowly that the plastic melts as you drill, otherwise the holes will have a rough side wall and the powder will not slide through it as easily.

After the hole plate is constructed, the last thing to make is the sliding plate. This is just a sheet cut from a scrap of Formica such that its width will fit the narrow track under the hole plate. The length of the sheet should extend from at least an inch before the hole array to about an inch outside the frame box so that there is enough to grab onto. It also helps to round off the corners on the end that is to be inserted into the frame. Note that there are thin types of Formica and a thicker type. The one you want is the thicker type. You should be able to get a scrap for free from any cabinet shop to avoid having to buy a full size sheet just to get a little piece. Otherwise you could also use 1/8" thick plexiglass as the slider plate and cut your track slot a little bigger than shown.

Using the Loader:
This is a fast tool to use once you have gone through the trouble to make it. Simply load up twenty five crossettes as seen in Figure 20, then place the box on top. Make sure the hole plate aligns with the center points of the crossettes, then insert the slider plate so that all the holes are closed off. A pile of 2Fg black powder (home-made in this case) is placed at the back of the box and dragged across the holes using a scrap of stiff cardboard cut to fit the entire width of the box as seen in Figure 21. The powder is then dragged back again to the back of the box on a second pass. Any excess powder should be scooped away so that the grains are level with the top each hole, as seen in Figure 22. Now simply pull out the slider plate as shown in Figure 23 and the charges will drop straight down into each crossette!

Sometimes a few grains will miss the cavity and collect on top of the crossettes. It is an easy matter to remove the frame box and tap the base plate from side to side while tilting it until all the grains on all the crossettes fall into their appropriate holes. This same tilting action also works for getting misplaced flash back into the holes after the flash loading step. Normally you would have to tap any spilled flash back into the hole one crossette at a time, but this holding fixture makes it easy to clean up batches of twenty five crossettes all at once!

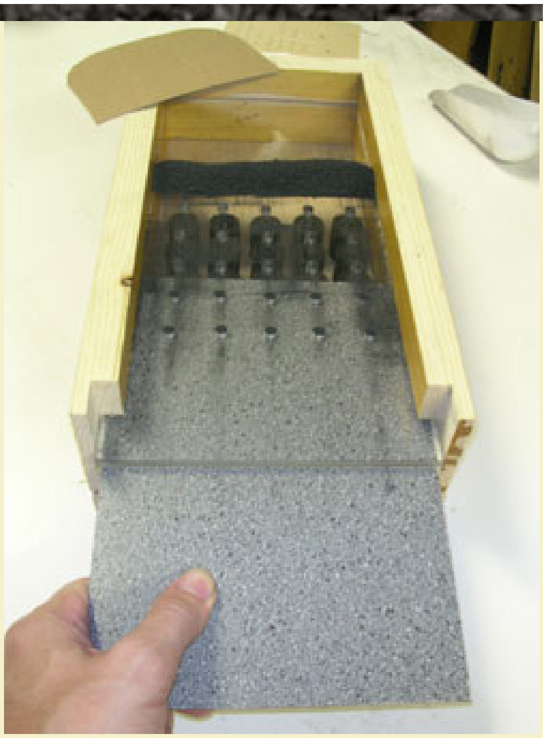

Figure 23: Pulling the barrier plate will drop the equally measured charges into the crossette cavities.

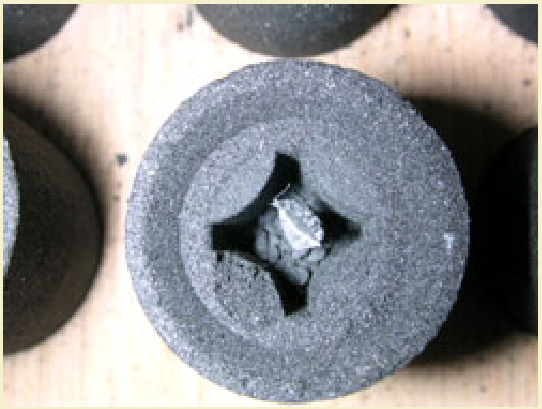

Figure 24: Close-up of charge dropped into crossette cavity.

Figure 24 shows a close-up of a crossette after it has been loaded. Note the presence of a paper Chinese style fuse at the center, which is inserted into the pin hole and cut flush with the top of the crossette. This fuse, which is made from granular corning dust using the method described here, is one of the tricks to getting both better breaks and better timing out of your crossettes. Using corning dust instead of standard meal to make the fuses results in a very fast burning fuse that will break the crossette at the exact instant that fire reaches the pin hole.

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Tool Tip...

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Building A Drying Box

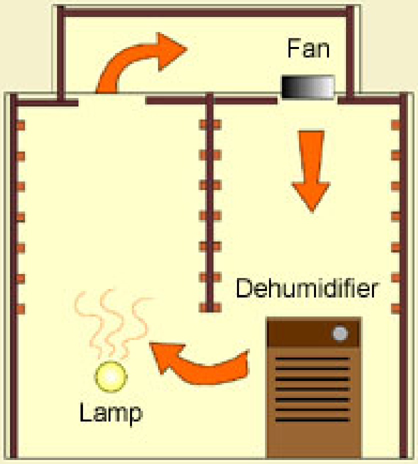

Figure 1: Two chamber design with circulated, warm dehumidified air.

Introduction:
Your guild is having a shoot in three days and you don't even have your stars made yet. You need to make your stars and have them dry in time to load a few shells and then dry the pasted shells before the weekend. Possible? It is if you have this dry box! I have gotten through many situations like the one mentioned above without being left empty handed on the field, all thanks to the speedy drying accelerator illustrated here.

There are a variety of methods commonly used for drying both stars and shells. The simplest is to set them out in the sun on a breezy day, but then you have to rely on the weather being optimal and even then you are limited to daylight hours. Placing pasted shells on screens or racks with a fan blowing across them can definitely speed the drying process. Some hobbyists use food dehydrators for accelerating the drying times of their stars.

There are three essential elements for maximized drying efficiency: elevated temperatures, low humidity and air circulation. Air flow is probably the biggest accelerator, with warm temperature the second biggest catalyst. Humidity becomes a problem only in enclosed places where the evaporating water has no place to go.

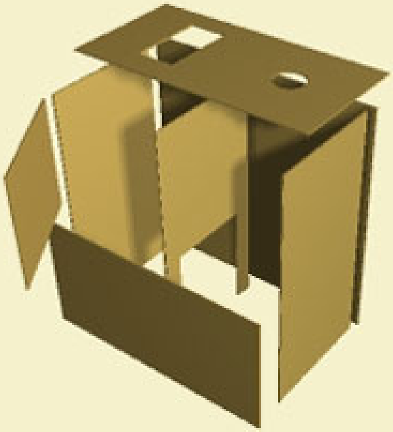

Figure 2: Plywood panel assembly.

Do-It-Yourself Drying Box
This drying chamber is compact enough to fit in most workshops yet still allows a lot of material to be dried at one time. The basic concept is a wooden box with two compartments separated by a half wall that allows air to flow from one chamber to the next. A fan is placed in a hole at the top of one chamber, which draws air from a hole in the top of the other chamber. This circular airflow passes by a dehumidifier to keep the air dry, and a light bulb is used to heat the air to about 100 degrees (varies depending on external temperatures). The sides of both chambers are fitted with runners to hold up to 14 screens total.

A second box is placed on top of the cabinet to act as an air duct between the chambers. This can be a wooden box that you build or even just a cardboard box that is taped down so that air can not leak in around it.

Figure 2 shows how the plywood pieces go together. I prefer the use of dado joints for assembling plywood cabinets of this type, but just butting the ends up against each other with wood glue between them and screwing them together with wood screws should work fine.

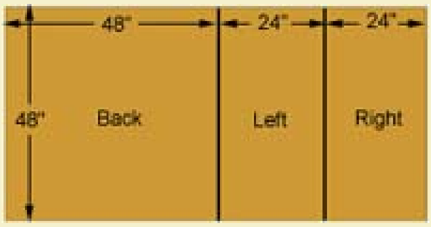

Figure 3 and 4 shows how the two pieces of plywood required to make the cabinet should be cut. The dimensions were chosen to create the least amount of waste and also require the least amount of cutting. A taller box that holds more screens could easily be made if you can afford another sheet of plywood.

Figure 3: Cut sheet for first 4x8 3/4" plywood sheet.

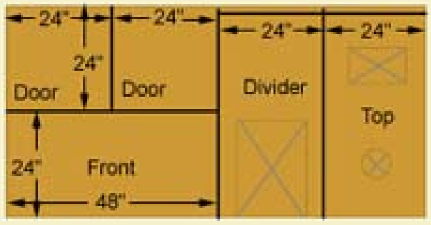

Figure 4: Cut sheet for second 4x8 3/4" plywood sheet.

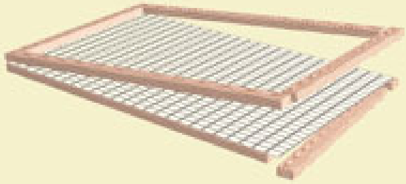

Figure 5: Drying screen construction.

The cutouts for the center wall and the top airflow holes are arbitrary, so don't worry about exact dimensions. You will want to obtain the fan you will use first before cutting out the round fan hole. A good source for surplus fans and other types of motors is MECI.

Screens

You will want to build a good number of screens to go along with your dryer. It is good to have a fine mesh screen like window screen for drying smaller stars, and strong screens made from 1/4" hardware cloth for drying heavier things like shells. The screens are made as shown in Figure 5, using two sets of 1"x3/4" wooden frame members to sandwich the screen between.

The corners of the frame sets are staggered so that the joints of the bottom and top do not align. Prefit the two frames on top of each other without the screen, square them up, and drill the pilot holes for the screws first. You will need to actually put in the screws as you go in order to keep the pieces from slipping out of square as you drill all the holes. When all the screws are in, back them out just enough to get the boards apart, then place the screen between them.

The window screen is easier to cut oversized and trim with a utility knife after the frame has been assembled. Hardware cloth should be cut to the correct size before framing.

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Drying Box

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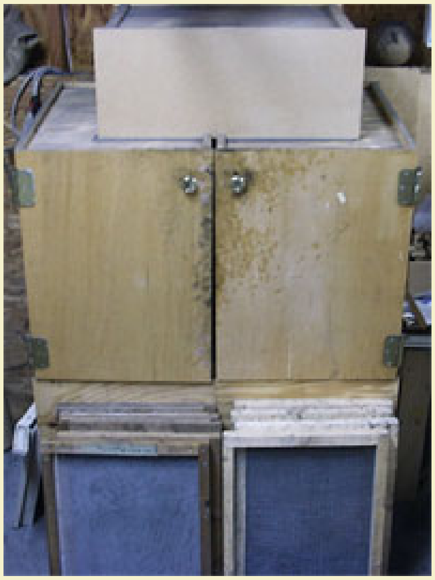

Figure 6: Drybox with screens.

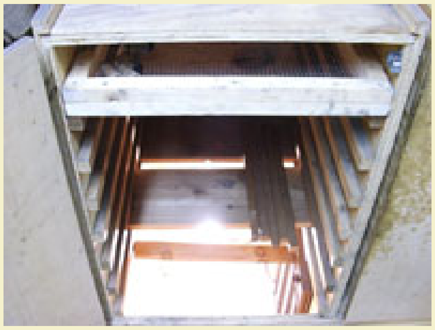

Figure 7: Left side contains high wattage bulb to provide heat.

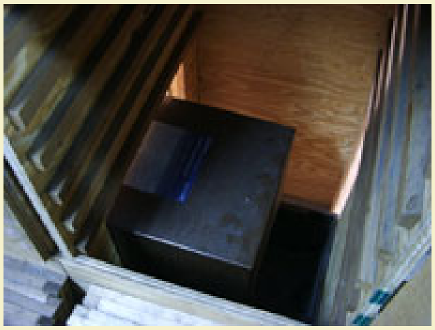

Figure 8: Right side contains dehumidifier to keep air dry.

The drying box shown in Figure 6 is not the full 48" wide as the plans here show, due to space limitations in my shop. It is also comprised of two single units pushed together, since my first dryer was only one compartment. Like everything pyro, more is better and I had to expand capacity without throwing out my original dryer. So you will see an odd seam down the middle that shouldn't be there if built correctly.

Figure 7 shows the left chamber with the 100W bulb for heat. Note that pieces of wood are used as shields above the bulb to prevent comp from falling onto the exposed bulb and causing a fire risk. The wooden slats that hold the screen are 23" long pieces of 1" x 3/4" pine nailed to the sides. A 2" spacer is used as a guide between the slats when nailing them in order to make sure they are all the same distance apart. These supports are easiest to attach to the side pieces before the cabinet is assembled.

Figure 8 shows a Sears dehumidifier at the bottom of the box. The water collection bucket can be emptied manually or fed out the side of the box with a hose.

Figure 9 and 10 shows the fan duct box at the top. The gray weather stripping is used to make a good seal around the edges of the box. Temperature inside the box is monitored using a Radio Shack temperature and humidity meter, seen in Figure 11. The outdoor probe is routed into the box so that the meter can be mounted elsewhere. For $20, this meter can measure two temperatures plus give you a humidity reading- which is a good safety feature to have in any pyro shop.

Fast Pyro:
This drying box can dry some types of stars within one day. Cut stars and small comets made from grainy type mixes will dry very fast. However, care must be taken when using this tool to force dry stars. Many types of stars such as round stars rolled from fine charcoal or lampblack mixes are very easily driven in, especially if they are placed on the right side directly under the fan. I generally use the less breezy chamber on the left for drying stars, while the right side is used for drying shells. Placing almost any kind of stars under the fan on the right will surely get them driven in. I usually let charcoal streamer type stars air dry outside the chamber for several days before even putting them into the dryer.

This box will dry a 4" comet in just one week (if it has a hole down the middle and was dampened with less than 10% water). It will dry a full load of vacu-form hemispheres in just one day. Pulverone, corned BP and break charges of rice hulls, cotton seeds and puffed rice cereal all dry within one day. Canister shells take about 2 days to dry, while ball shells about 4 depending on the number of pasted layers and the temperature inside the box. Temperatures around 100 degrees are ideal.

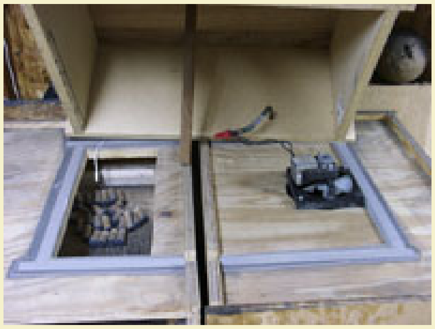

Figure 9: Underneath the air hood on top.

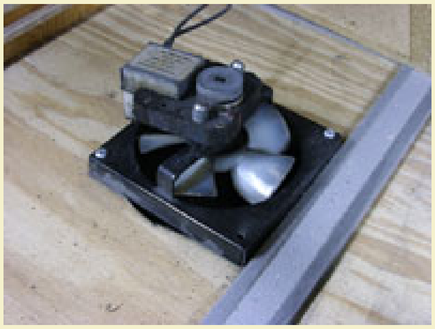

Figure 10: Small fan circulates air through the chambers.

Figure 11: Radio Shack temperature/ humidity gauge.

There are probably many variations of drying boxes you can build to achieve the same effect. As long as you can get warm, dry circulated air flowing around your screens then you will see drastically faster drying times. Once you start using something like this, you will wonder how you ever got along without it!

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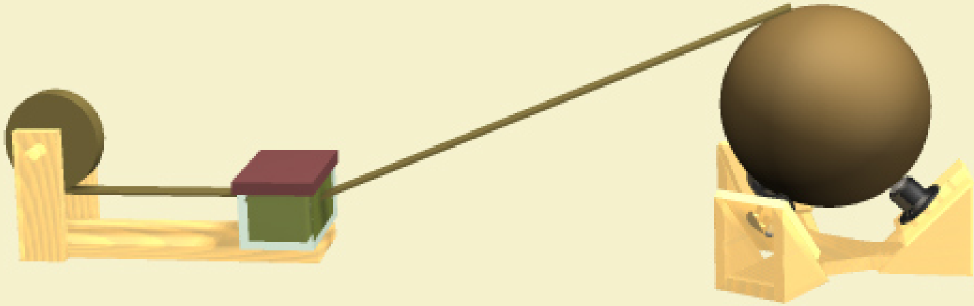
Tool Tip... **Page 1**

Gummed Tape Pasting Station



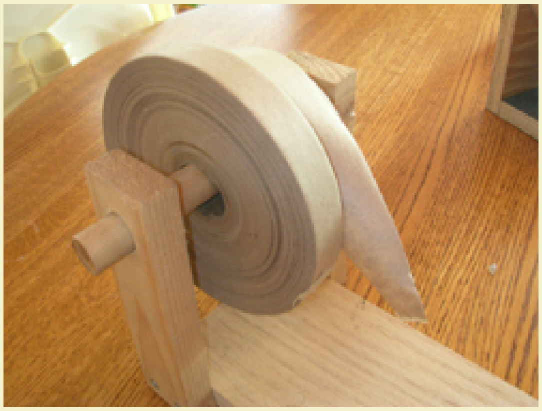


Figure 1: Removable dowel rod to hold the tape rolls.

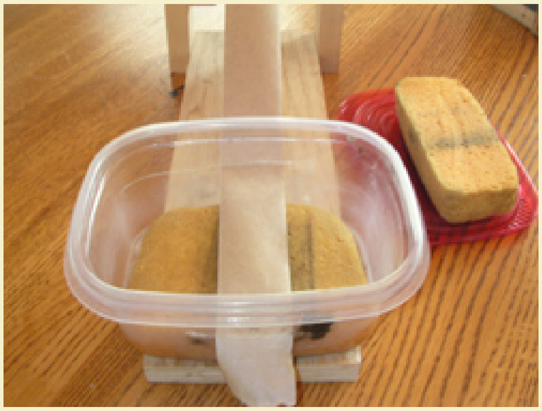


Figure 2: Tape passing over the bottom sponge.

Introduction:
The gummed tape dispensing station shown here consists of two components: the tape dispenser and a holding fixture for the ball shell being pasted. The tape dispenser holds a roll of gummed tape so that it can be spooled off onto the shell being taped, and also wets the tape as it is being applied. The tape runs through a plastic container full of water, which also holds two sponges between which the tape passes through. This effectively wets the gummed side of the tape in order to activate the binder prior to being applied to your shell.

This type of dispenser is very common and is optimal for taping techniques that use one continuous piece of tape when covering the shell. For taping methods that require placing a pattern of many small strips to cover the shell, having to continually tear or cut off strips would tend to gum up your fingers or your scissors. There are actually commercial tape dispensers that allow you to dial in a length of tape and hit a button to automatically dispense a wetted strip of tape of a desired length, which is a better setup for using multi-strip taping methods.

The optional shell rolling fixture is really only useful for shells larger than 6" diameter, which can be heavy and tiresome to manipulate by hand. The fixture supports the weight of the shell on three equally spaced roller bearings, and can accommodate shells from 8" all the way up to 16". This fixture not only takes the weight of the shell off your hands, it allows the shell to be easily rotated in any direction while rolling on strips of gummed tape.

Building the Dispenser
The tape dispenser is very simple to make and the dimensions are not all that critical. It might be best to first obtain the rolls of gummed tape that you plan to use, then dimension your holding fixture to accommodate the size of your rolls.

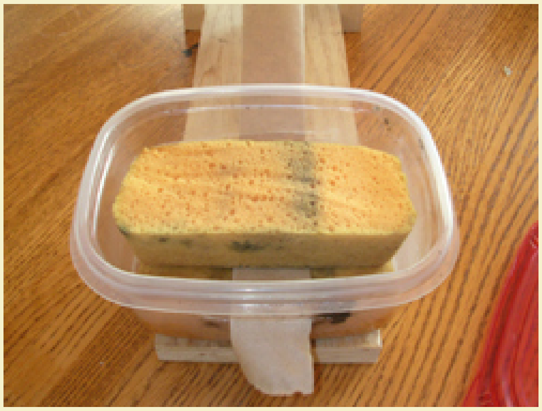


Figure 3: Top sponge put in place.

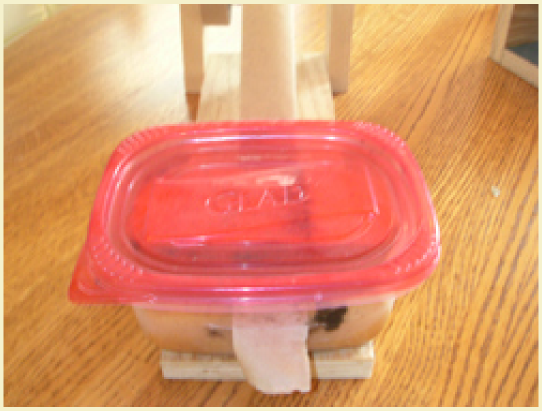


Figure 4: Dispenser is filled with water and ready to use.

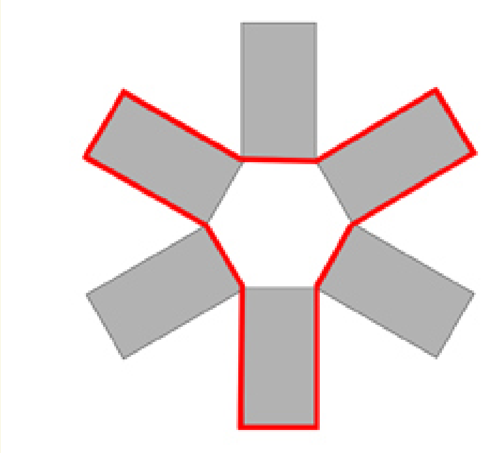


Figure 5: Creating the base plate layout.

The dispenser shown here uses a base plate that is 5" wide and 12" long, made from 3/4" thick plywood. Two pieces of wood measuring 7" long by 1.5" wide are used for holding the spool, each of which has a 3/4" diameter hole drilled one inch down from one end. The holding arms are screwed to the sides of the base board flush with one end, as seen in Figure 1. A piece of 3/4" dowel rod is passed through the holes in order to hold the tape spools. There is no need for using roller bearings unless your tape spools are unusually large, which is not likely. A simple unsecured dowel rod with a relatively close fit in the holes will work just fine for holding the tape rolls as they spin.

The opposite end of the base plate needs to have a plastic container attached to it for holding water and the sponges. The size of this container will determine how often it has to be refilled with water. The container shown here is a typical zip-lock disposable type container, although anything will work fine. I used hot glue to secure the container to the base board, which is quick and dirty but doesn't always hold the best. Running small screws through the bottom of the container in order to attach it to the base plate would be much more secure, although you would have to be sure and put silicone over the screws to prevent the water from leaking out around them.

A set of sponges is used to sandwich the tape as it passes through the container, which serves to transfer the water onto the tape without concern for the water level in the dish. The water level in the container can only be filled level to the top of the bottom sponge, so the bottom sponge should be much thicker than the top sponge. The top sponge only serves to hold pressure against the tape so that it makes good contact with the main sponge, so it should be cut to a thickness that allows it to stick up just above the top of the container when placed on top of the bottom sponge. This way there will be some compression when the lid is placed on the container. You do not want too much compression however, otherwise the tape can become too hard to pull through and it will frequently rip.

A good quality sponge should be used here, as some cheaper sponges will rot and crumble if stored in water for very long. The thick sponges sold in hardware stores for doing tile work will work good, although similar quality sponges that are already cut down to a small square can usually be found in the cleaning isle of any grocery store.

Two narrow slits must be cut through both sides of the plastic container so that the paper tape can pass through it. These slots should be located just above the top of the bottom sponge as seen in Figure 2, such that water will not leak out of the slots when the dish is filled to the top of the sponge. An Exacto blade or carpet knife works good for making these slots.

Using the Dispenser
The best way to setup the tape dispenser is to clamp it to the edge of your work table using a C clamp or bar clamp. This way it won't slide as you pull the tape through it. For smaller shells you would simply hold the shell in your hands to spin it while pulling the tape from the dispenser. For larger shells 8" and beyond it is best to build the roller jig described below for holding the shell while you work.

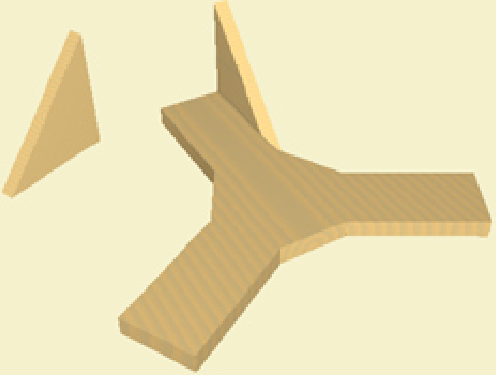


Figure 6: Attaching angle brakets to the base plate.

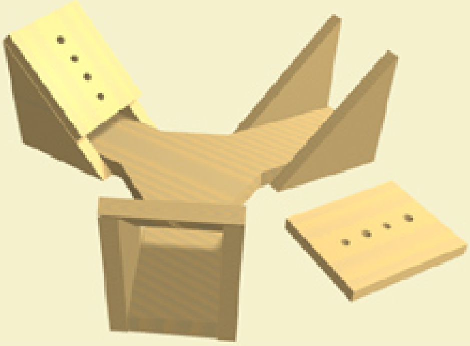


Figure 7: Hole plates are attached to the angle brackets.

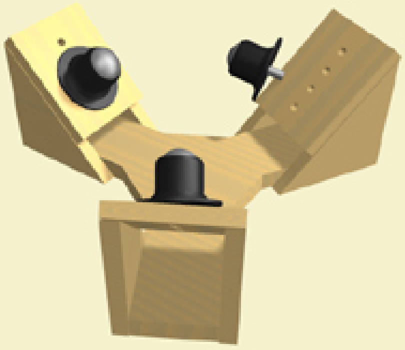


Figure 8: Inserting the roller bearings.

Depending on the size of your water container, you will have to refill it after every 2 or 3 shells. One way to reduce how often you refill the container is to fit it with an inverted water bottle that will maintain a fixed water level in the dish. This is similar to how some of the automatic pet feeders work. You might even be able to modify a pet feeder water dish to use as your sponge container if you will be making a large quantity of shells and don't want to be bothered with refilling the water all the time.

When the tape is allowed to sit between the sponges for too long during a taping session, it will become too saturated and rip easily as it is pulled from the container. Since re-threading a new piece of tape can take a minute or two each time, it is best to keep the tape rolling once you start. Otherwise a soggy piece of tape can still be carefully pulled out and torn off to start a new strip without having to rethread the tape.

Building the Roller
The ball shell roller uses three stud mounted ball roller bearings, which were ordered from McMaster-Carr (part number 6460 K47) for $10.48 each. So the first step would be to order three of these from the McMaster website at www.mcmaster.com.

The only tricky part to make is the triangular base plate, which is made from 3/4" thick plywood. The best way to layout the cutting lines for this piece is to make six squares of cardboard that measuer 5" long x 2-3/4" wide and arrange them in a circle so that all their corners touch. Then use a pencil to trace around the squares so that you create the pattern shown by the red line in Figure 5. A bandsaw or jig saw is then used to cut out this piece.

After making the bottom plate, cut three blocks of 3/4" thick wood that measures 5" square. Draw a diagonal line between the corners of each square and cut on this line to produce six triangular pieces that measure 5" on the short sides. These triangles are then attached to the base plate on all three arms as seen in Figure 6. Nails, screws or glue can be used for this.

The last step is to make three blocks of 3/4" thick wood that measure 5-1/4" long by 4-1/4" wide. You will need to drill four equally spaced 3/8" diameter holes down the center, with a 1" spacing between the center of each hole. The first hole starts 1" down from the top edge of the block. The hole blocks are then attached to the angle brackets as seen in Figure 7.

The roller bearings can now be dropped into the hole plates to handle different size shells. The bottom hole is for 8" shells, while 10", 12" and 16" require the bearings to be moved up to the next size hole respectively.

Using the Roller
When using the dispenser with the roller, the dispenser is clamped to the opposite side of your work table so that it faces you, then the roller is set on the table in front of you. Note that this roller can only be used when gum taping ball shells that do not have the time fuse installed yet. Otherwise the time fuse will hit the rollers as you spin

the shell. Because gummed tape is easier to cut through once it dries as compared to traditionally pasted paper, installing the time fuse after the tape is already applied is a viable option that makes the taping go easier. Although the lack of a fixed reference point on the shell can make keeping track of your taping pattern more difficult when you first try learning this technique.

Figures 9 and 10 show just how large of a shell can be handled with this fixture. Even a very heavy 16" shell still rolls with ease!

Note that this roller should not be used when pasting shells in the traditional way, as the paste would get down inside the rollers and rust them out. You might be able to find some corrosion proof rollers (stainless or plastic), but the paste would still dry on the inside and gum them up unless you hosed them off after each use. For people who regularly paste in large 12" and 16" shells it might be worth the trouble of finding suitable rollers and try using this jig with the post-time fuse insertion method, only locate and punch the time fuse hole while the paper is still wet. I have not tried this myself, as I have been sold on the ease and speed of using gummed tape over traditional pasting, but some readers may wish to give it a try.

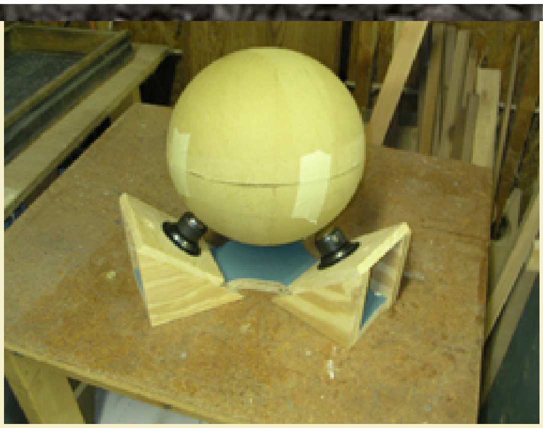


Figure 9: A 10" shell on the roller.

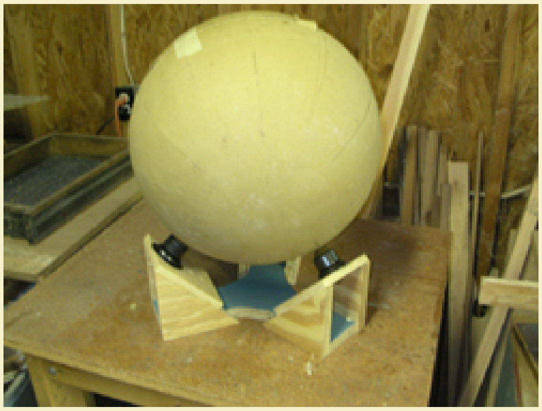


Figure 10: A 16" shell on the roller.

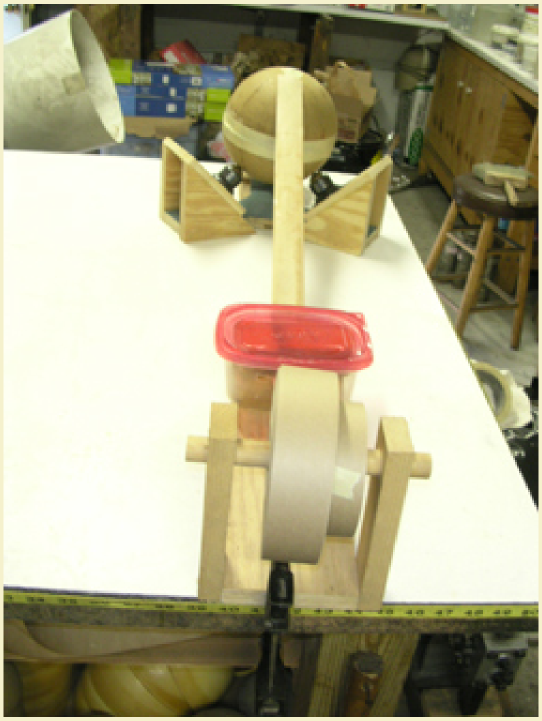


Figure 11: The tape dispenser and shell roller setup for use.

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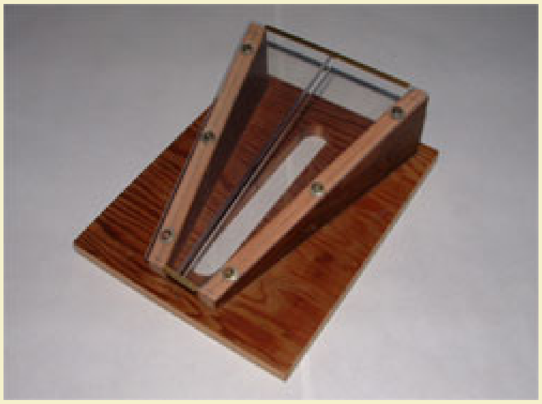
Volume 5, Issue 5

Tool Tip... **Page 1**

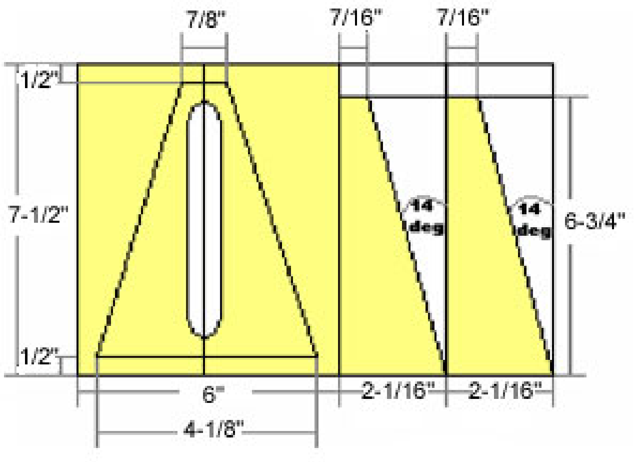
Hemisphere Center Marker

by **James Hughes**



Materials:

- (1) 10-1/2" by 7-1/2" wood, 3/8 " to 1/2" thick
- (1) 3-1/2" by 6-3/4" acrylic or Perspex sheet, 1/8" thick
- (1) 6" long section of 1/8" brass channel
- (6) 3mm x 12mm wood screws
- (6) 3.5mm x 25mm wood screws



Introduction

Have you ever wished you had a quick and easy method of marking the centre point of a shell hemisphere for drilling the fuse hole? Especially if you have a large quantity to do! Doubtless some of you will be familiar with the problem of stars layering up out of level with the lip of the hemi when filling stars in concentric layers around a fuse that has been positioned off center. This leaves the builder no option but to leave gaps around the equator that can result in rattles and sparse areas in the burst, especially in smaller shells.

The tool I designed to overcome these problems is constructed around a hollow wedge. The hemisphere is inserted all the way into the wedge until it won't go any further, then a pen is used to mark the center point through a slot that is centered above the hemi. The jig described here can be used to find the center of all hemispheres between 1" and 3.5" in diameter. A larger jig could also be made to handle bigger hemispheres just as easily.

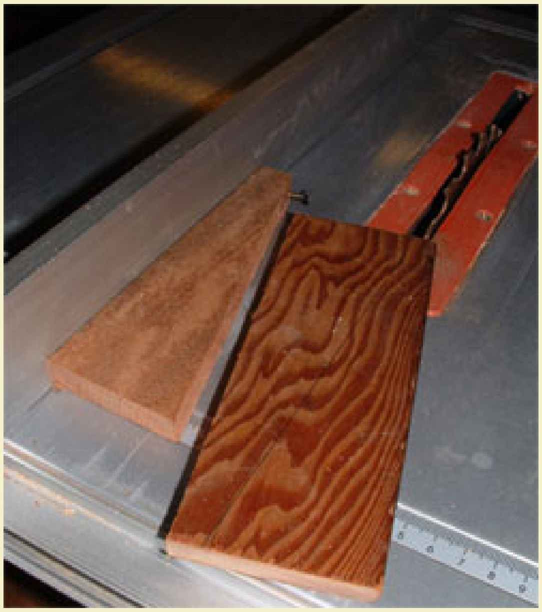


Figure 1: Using angled block against the

Construction

The top plate of the wedge is made from clear Perspex or acrylic, while the sides and base are cut from any panel wood (ply, MDF etc.)

guide fence to hold a side piece at 14 degrees when cutting the slope.

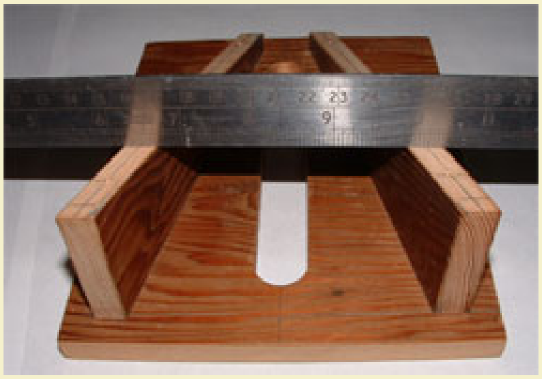


Figure 2: Making sure the top edges are on a level plane.

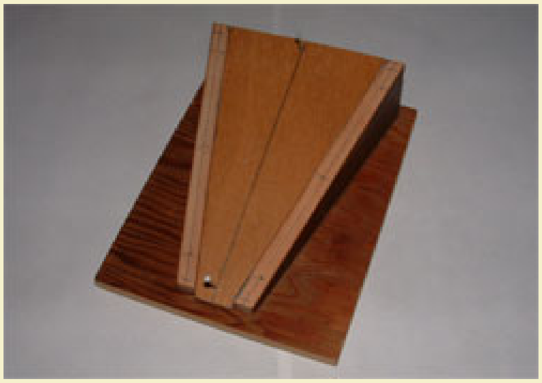


Figure 3: A temporary slot width guide for centering the plastic sheets.

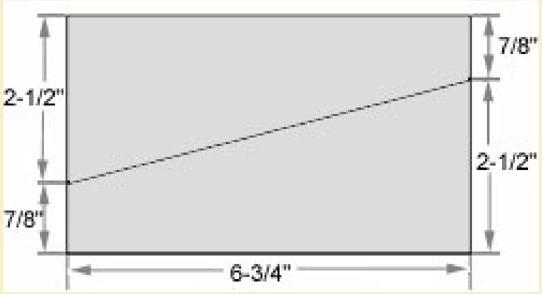


Figure 4: Dimensions for the clear plastic sheet.

approximately 3/8" to ½"" thick. The components are first marked out on the wood and cut to size according to the dimensions shown in diagram above. Mark out the wedge shape and the position of the slot on the base.

The slot in the bottom of the base is a finger hole for fishing the hemis back out of the jig once they are marked. If you do not wish to cut this slot, a pusher stick can alternatively be used to push the marked hemis back out once marked. However, the extra time spent making the slot now will save you more time later.

The base slot is made using a router table or a hand held jig saw. When using the jig saw method, a 3/4" hole is drilled one inch from the center at both ends, then the jig saw is used to cut straight lines between them to remove the piece. When using a router table, a hole is drilled near one end of the slot to accept a 3/4" straight edge router cutter. The fence is set on the router table so that the slot is centered. If you only have a small diameter router cutter then a wider slot can be made by offsetting the center of the cutter, making the cut then turning around to cut the other side.

Two strips are now to be cut for the sides. The angle is cut on a table saw by using a right angled triangular guide block with a 14 degree angle. A small screw is driven in near the end to prevent the two pieces of wood slipping past each other, as shown in figure 1.

Once the side pieces are cut, they are aligned with the marks on the base and secured with screws that run through the bottom of the base and up into the walls.

Next a rectangular sheet of Perspex is marked out to the dimensions shown in figure 4, and the two right angled triangles cut out. The top edges of the diagonal cut should then be beveled slightly to make access with a pen easier.

It will be found that when the top Perspex sections are placed on top of the base unit, the plates will not rest parallel with the base. This will cause the Perspex sheet to become angled downward when screwed down on top, and be too low at the center point. This phenomenon will be more pronounced if the sides are made of a thicker wood. Therefore, the tops should be planed or sanded carefully so that a straight edge will lie flat across the side walls as shown in figure 2. In order to make this task easier, the top sides can be colored with a permanent marker and sanded until only a very thin line is left on the inner edge. Do not sand away any of the inner edge, if you do you can correct the error by placing washers beneath the Perspex when it is screwed down.

The final step is to attach the Perspex sections to the side walls. This must be done so that there is a sufficient gap to accept a pen nib and must be perfectly centered. The gap should be adjusted to the particular pen that is used. I have found that a fine permanent OHP marker or a fine-liner type pen that has a thin, metal, tubular section before the tip to be particularly suited to the task.

To perfectly center the gap between the two sections a wooden jig is cut so that it fits snuggly in the top. A center line is marked on it and two fine panel pins are driven in, one at each end as shown in figure 3.

Drill 3 clearance holes in each of the Perspex sections, countersink and screw them in place, with the short screws, while holding them up against the panel pins, as shown in figure 5.

The jig can now be slid out and to finish the tool a section of 1/8" brass channel can be glued across the front and back edges of the Perspex top sheet to offer added support.

To use the jig, simply insert a hemi into the wedge and push it forward until it won't go any further. Use a pen to mark the top contact point, as seen in Figure 6. You can then rotate the hemi 90 degrees and mark a second line to get the exact center point. The hemi is then ejected by using your finger through the base slot to fish it out, and you'll have a perfectly centered mark every time!

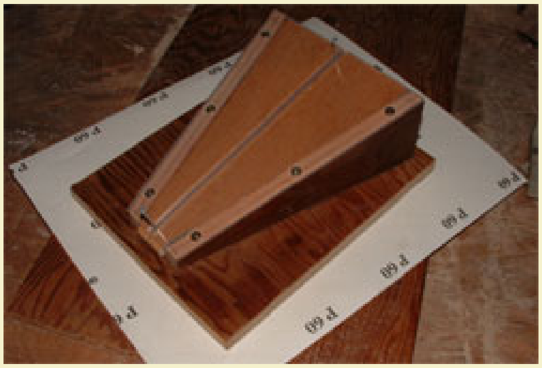


Figure 5: Attaching the two plastic guide sheets.

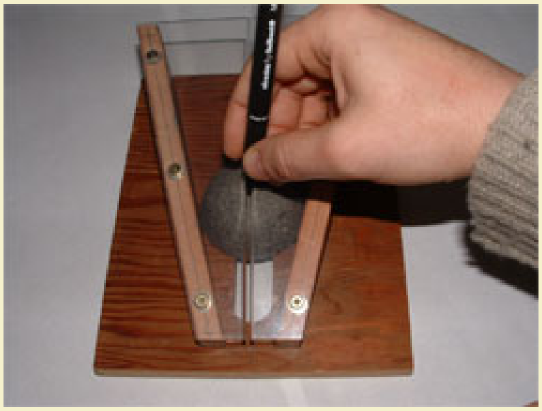


Figure 6: Using the finished center marking jig.

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Volume 4, Issue 4

Home Made Star Plate

by ***Kyle Kepley***

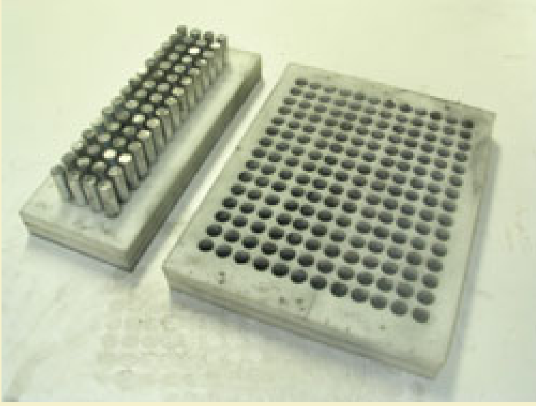

Figure 1: A 180 hole star plate with 60 pin plunger.

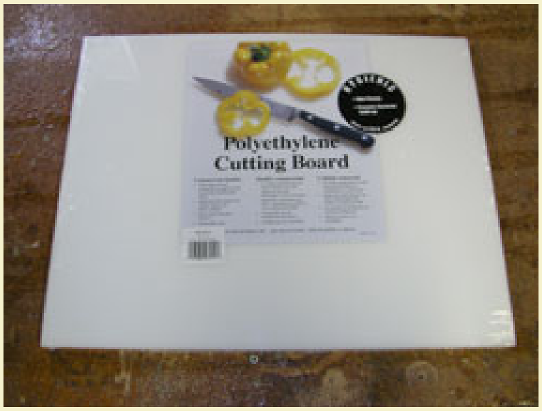

Figure 2: Polyethelene cutting board from Home Depot.

Materials:

- (1) 18" x 14" x 1/2" thick chopping block
- (3) 36" long x 3/8" diameter aluminum or brass rods
- (1) 3/8" or 23/64" drill bit
- (1) 23/64" or 13/32" drill bit
- (2) 1" to 2" long 1/8" diameter rods or nails
- Carpet tape

Introduction:

Pumped stars are the most precision type of stars you can make, and their ease of ignition is second only to cut stars. Their cylindrical shape is also ideal for roman candles, comets and other projectiles fired from a tube. However, pumping them one at a time is a time consuming activity that is too much work when large quantities are needed.

Star plates are the only practical way to go about making pumped stars in any useful quantity. As seen in Figure 1, a star plate is simply a plate full of holes with a matching pin plate that mates with it. The procedure for using such a plate is described here.

Most commercial star plates are made of machined aluminum or brass, and they can be rather expensive. If you were to purchase a commercial plate of the size shown here, you would likely pay a few hundred dollars for it. Following the instructions given here, you can make your own star plate capable of pumping out 180 3/8" stars for only about $25 using parts available at any Home Depot hardware stores.

Acquiring Materials:

The hardest part about making your own star plates is finding a suitable material for the plate itself. It has to be the right thickness, be rigid, hold up to solvents and allow easy machining. Aluminum is the ideal material due to its strength, weight and resistance to solvents. However, it can be rather expensive in thicker sizes and requires more time, skill and tools to work with. Plastics such as plexiglass will also work, except thicker sheets are hard to find and

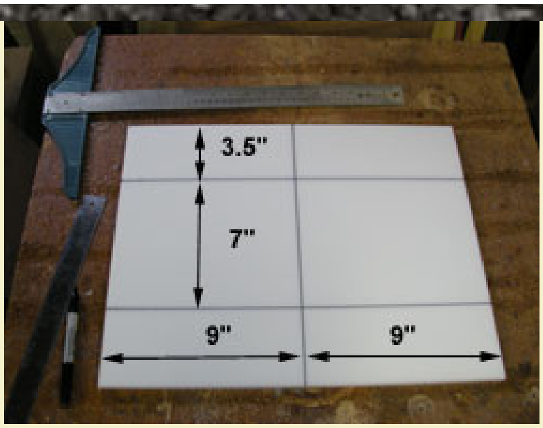

Figure 3: Marking the cutting lines with a felt tip marker.

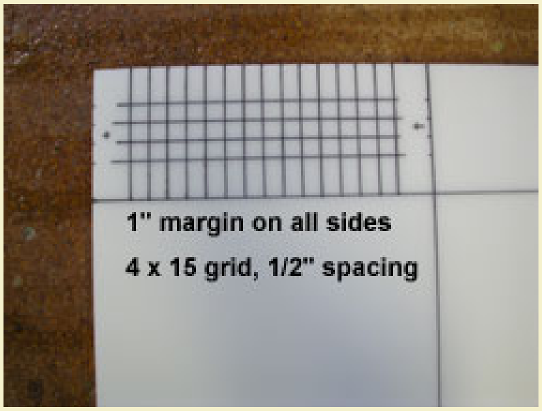

Figure 4: Marking the hole centerpoint grid.

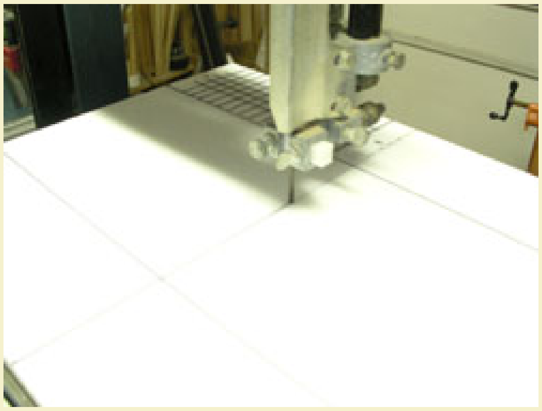

Figure 5: Cutting out the pieces on a band saw.

prohibitively expensive when you do find them. Most plastics also will melt if used with acetone or other solvents used in pumping certain types of stars. The nice part about using plastic is that the pins can be secured in place using glue, unlike the aluminum pins that must be individually fastened with set screws.

Luckily it is possible to find polyethylene cutting boards that work well for making your own star plates. Home Depot sells a particularly large one without any fancy grooves around the edges, which is well suited to this project (see Figure 2). The board is 1/2" thick, which is a good size for making a range of star plates. Larger plates are made by stacking the boards together to form thicker plates. A 1/4" star plate uses just one sheet, a 3/8" plate uses two sheets, and a 1/2" plate uses 3 sheets sandwiched together.

Polyethylene can not be melted by any solvents that I know of, which is good and bad. It is good in that the finished star plate will hold up to anything you expose it to, but bad in that there is no way to easily glue multiple sheets together. I've tried epoxy, glues and even carpet tape in an attempt to hold parallel sheets together, but all came apart eventually. The only good way to keep the plates together is to weld the edges together using heat to melt the plastic.

Aluminum pins are used for the pin plate, and these are easily found in most hardware stores as 36" long rods in various diameters. You will need to get three 3/8" diameter rods, but be careful in selecting them, since the rods found in most stores are not very exact in their diameter. Some are slightly less than 3/8", while others are slightly more. This means you need to get a drill bit gauge from somewhere else in the store and use it to gauge each rod to make sure they are all the same size.

Because the pins will be press fit into the pin plate, the pins actually need to be very slightly larger than the holes they will fit into. When choosing your rods, you can select three that fail to fit into the 3/8" drill guide hole, then use a 3/8" bit to drill out the pin plate. If you can only find rods that are actually the correct diameter and fit into the hole, then you will need to buy a 23/64" bit for drilling out the pin plate holes. Before drilling out your pin plate, be sure to test fit your rods into a test hole drilled in a piece of scrap plastic. The pin should fit tight enough to require a hammer to tap it into place, and you should not be able to pull it out by hand.

Construction:
Figure 3 shows the cutting lines for the 18" x 14"

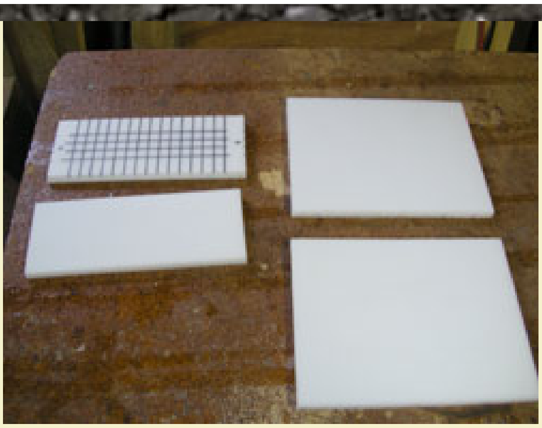

Figure 6: Two sets of identical pieces to be joined together.

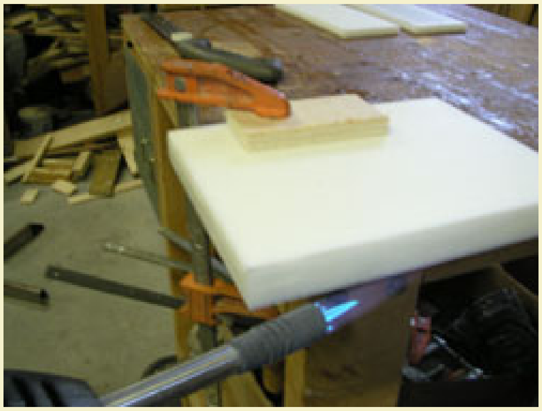

Figure 7: Using a blowtorch to heat the edges when melting the two pieces together into one thick piece.

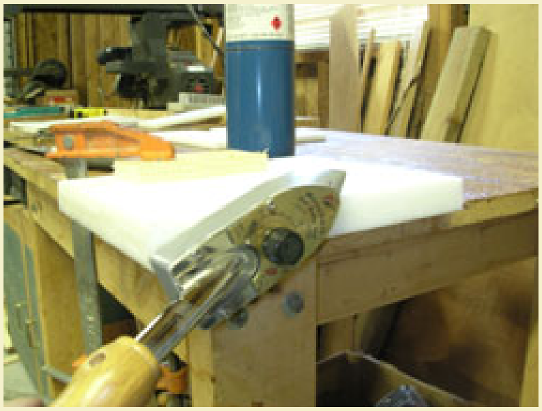

Figure 8: Using a monokote hobby iron to aid in melting the seam together.

sheet sold at Home Depot ($12 at time of this writing). It is also a good idea to lay out your pin grid at this time, as seen in Figure 4. Note the center points marked on each edge for the alignment pin holes. These are located 3/8" from each edge and centered as shown.

A band saw is ideal for cutting out the pieces, as seen in Figure 5, since the material removed by the thin blade is so small that you don't have to account for it. Polyetheylene cuts and drills very easily and it will not chip or crack, which is another nice thing about it. If you don't have a band saw, you could probably clamp the piece to a table and use a thin hand saw to cut out the pieces. The edges do not have to be pretty, and you are going to melt any ugly cut marks when joining the pieces together.

Figure 6 shows the four pieces you will need to cut out. There will be two other leftover pieces, which you can use as a backing when punching spolette holes in disks or as a hot glue drip pad. You can even cut it into cubes and use it for replacement blade guides for your band saw, which you can see on my own saw in Figure 5 (white cube next to blade).

Next you will need to join the two big plates together to form one thick plate. If you plan to pump stars using the method shown here, then you don't have to join two plates together and can ignore this step. However, if you prefer to pump stars using the granulation method shown here, then you will need the double thick plate.

Like I mentioned, trying to glue this material together is hopeless. You have to seal the edges together using heat. Figure 7 shows a blowtorch used to heat the edges while the two pieces are clamped together on the edge of a table. A monokote hobby iron, which can be found in most hobby shops for building remote control airplanes, will help smear the melted plastic around when doing this. You could also just heat a metal trowel with your torch and use it the same way. All four edges need to be melted together as shown.

This star plate design uses a 1/3 size pin plate in order to save you time and money, as well as to reduce binding problems when inserting and removing the pin plate. You only need to make 60 pins to have a 180 capacity plate. When you start cutting those pins, trimming the burrs and sanding the face of each one, you will thank me for cutting your work by 66%. You're welcome!

Now, the pin plate will be used as a template for drilling three sets of holes. Thus there will be three sets of alignment holes needed for the three positions it will be in during this process. Figure 9 shows the guide lines you will need to draw on the plate, which will be used to line up the edge of the pin plate when drilling the alignment pin holes. The dotted line is the third position, and it will align with the back edge of the plate, while the solid lines will align with the front edge of the pin plate from the perspective shown in Figure 9.

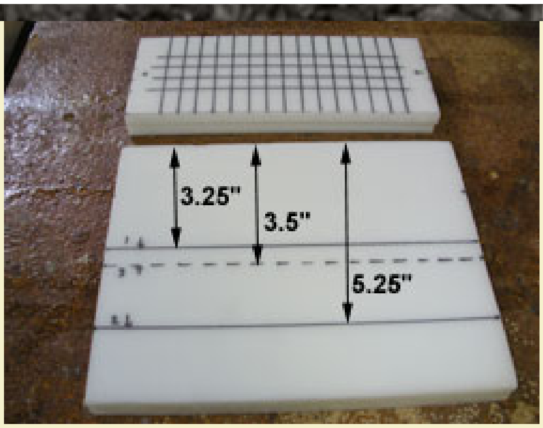

Figure 9: Alignment markers on hole plate to aid hole template placement.

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Home-Made Star Plate...

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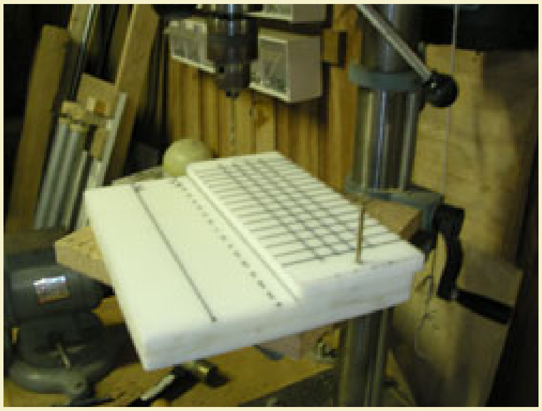

Figure 10: Drilling 1/8" holes for alignment pins.

Figure 10 shows the pin plate being aligned on top of the hole plate, with one brass pin already in place. It is important to drill and insert the pin on one side before drilling the other side, otherwise the plate will slip on you and the holes will not be aligned.

After pinning the first position, remove the holding pin and relocate the pin plate to the second position, which is the solid line below the dotted line. Drill and pin one side as described already. Finally, move the plate to the last position and pin both sides. At this point you can just leave the plate pinned on both sides because the next step is drilling out the holes.

Now you are ready for the dreaded task of drilling 180 holes. If this were aluminum, then it would probably take you all day to drill this many holes due to the slower drilling speed, using cutting oil etc. However, the polyethylene drills quite easily and fast. Figure 11 shows the drilling in progress. The wire brush shown here can be used to clean the turnings off the drill bit without the need to turn the drill press off and on 180 times during this tiresome process.

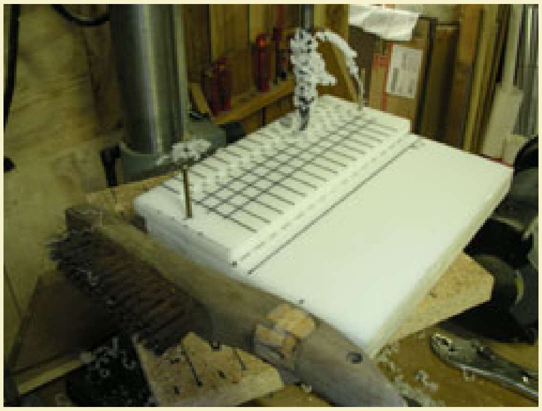

Figure 11: Drilling pin plate and first set of plate holes.

For the first set of holes, you will be drilling through both the pin plate and then all the way through the hole plate. Once all 60 pin plate holes have been drilled, the plate is moved to the next position and serves as a template to guide the bit when drilling the next set of 60 holes in the hole plate. And if that isn't exciting enough, you get to move the pin plate one more time to drill the final set of 60 holes.

Once all the holes are drilled, and I hate to say this, but you have to re-drill all 180 of the holes in the hole plate with a slightly larger drill bit. These holes need to be a tad bit larger than the pins that will fit into them, otherwise the pins will bind. If your aluminum rods were the slightly oversized variety and you used a 3/8" bit to drill the plate holes, you will need a 27/64" bit to resize the holes. Otherwise you can use a 13/32" bit. Either way it is an oddball size that is probably going to cost you a trip to the hardware store. Make sure you get the standard type of bit with a tapered tip, since you will be drilling without a center point to guide the bit.

Do not be tempted to make these holes any larger than you absolutely have to, otherwise your stars will have little rims around the top if the pin clearance is too much. The openings of each hole in the hole plate can be trimmed by hand twisting a large diameter bit into the hole opening, such as a 3/4" bit. It is important that both sides of the hole plate are smooth and flat, so any extrusions caused by the drilling process need to be reamed out in this way.

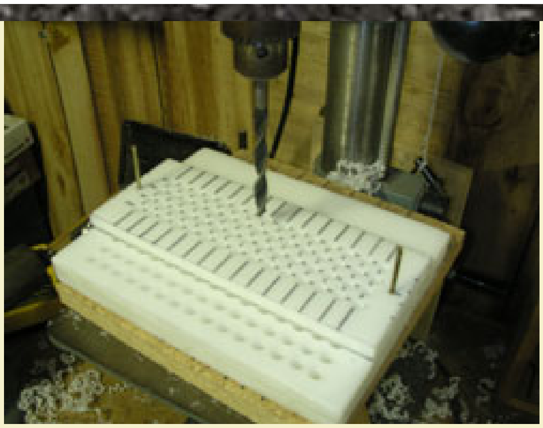

Figure 12: Drilling second group of holes using pin plate as a guide.

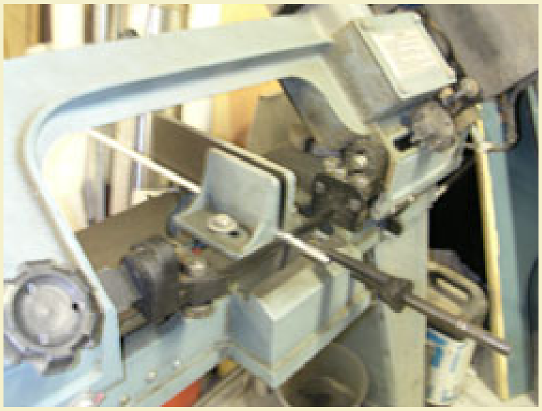

Figure 13: Cutting pins using a horizontal type band saw.

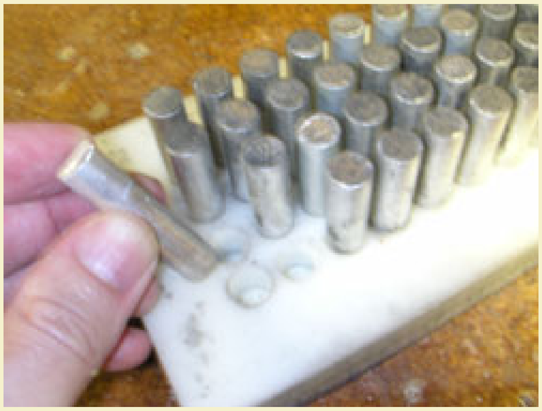

Figure 14: Installing pins in pin plate.

Once all the holes are bored out to the larger size, you have only one grueling, monotonous task left: cut 60 aluminum pins that are 1-1/2" long from your three rods. If you are using the single 1/2" thick hole plate, then the rods only need to be 1" long.

If you are lucky enough to have a horizontal band saw, such as the one shown in Figure 13 (lucky me), then you can make short work of the cutting process. This type of saw has a stop-block for consistently cutting lengths of material to the same size. The stock is fed into the back by hand and the hinged bandsaw assembly is brought down on top of it to make rapid cuts. The alternative is a hand held metal cutting saw and a lot of elbow grease.

Once all your pins are cut, you will need to clean up the rough edges and sand one end of them smooth. I use a belt sander mounted on it's side for doing this, but a table grinder can do the job just as well.

With all your pins cut and cleaned up, the worst is over. Now all you need to do is assemble the pin plate and you are done. Start by taking the pin plate that doesn't have the holes in it and melting it onto the piece that does have the holes, using the same technique you used to join the two hole plate pieces together. Be sure that the side of the drilled out plate with the guide lines is covered by the top plate.

All that is left now is to tap each pin into the holes in the hole plate, making sure they seat all the way down to the backing plate. Figure 14 shows this last step in progress. The flexible quality of the polyethylene makes press fitting the pins a very simple and effective way to hold them in place. This technique would not be possible with more brittle types of plastic such as acrylic.

With the right tools, this project can be completed in about 3 or 4 hours. The parts are easy to find and the cost is very low. The only drawback is the monotony of dealing with so many holes and pins. But once the project is complete, your pumped star production will be drastically increased and the plate will likely last you forever.

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Tool Tip... **Page 1**

A Simple Hydraulic Press

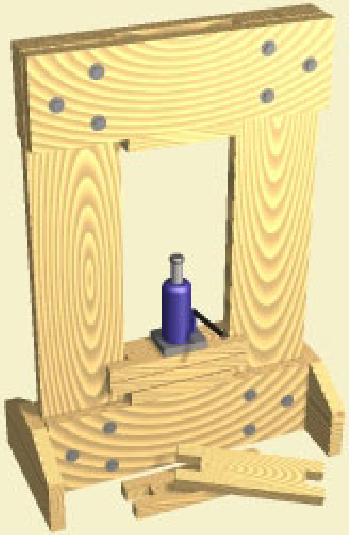
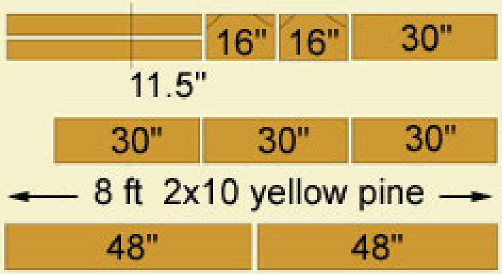


Figure 1: A simple wooden frame with bottle jack.

Introduction:

Since metal 'H' frame hydraulic presses are relatively cheap ($100 for a typical frame suitable for pyrotechnics) it may not seem worth it to make your own. However, some people may not be able to buy a press locally or have a tight pyro budget, so I thought this wooden version that can be easily built was worth showing.

The press shown here is probably overkill in the amount of pressure it can handle, but I just wanted to be sure it wouldn't come apart. It is made from 2x10 yellow pine lumber and held together by 3/8" bolts that run all the way through the timbers. You could probably get away with using 2x6 yellow pine and 1/2" bolts to get the cost down further. The 30" cross members would have to be shortened accordingly if switching the lumber dimension. Be sure to avoid spruce lumber, which is lighter and not nearly as strong as yellow pine. Using pressure treated (PT)lumber will insure you have good strong wood as well.



Materials:

- (3) 8 ft long 2x10s, yellow pine or PT
- (12) 5" long 3/8" bolts
- (12) 3/8" nuts
- (24) 3/8" washers
- (16) 3" long 1/4" lag screws
- (16) 1/4" washers

Tools:

- skill saw
- 3/16" drill bit
- 7/16" spade bit
- 3/4" spade bit
- drill

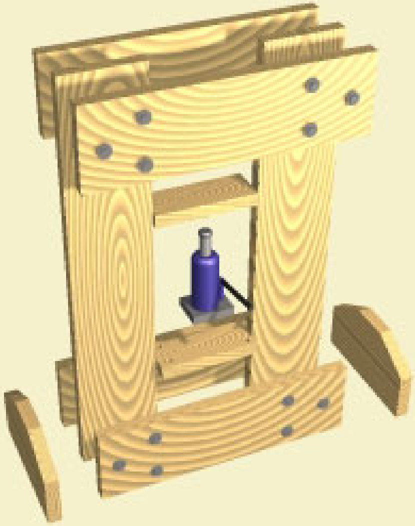


Figure 2: Exploded view of frame.

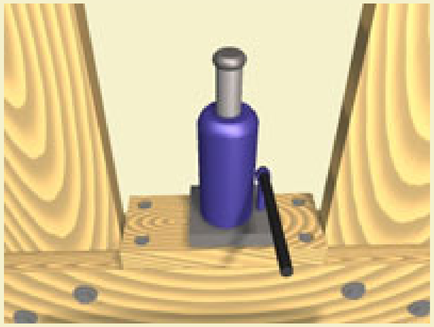


Figure 3: Bottom and top plates held down with countersunk lag screws.

Construction:
Start by making all the cross cuts shown on the cut sheet above, then make the one rip cut shown exactly down the center of the board. This will give you two 4.5" wide pieces, from which you will cross cut two 11.5" long pieces. Cutting the bevels on the two 16" pieces is just for looks and you can make the angle anything you want.

Figure 2 shows how all these pieces go together. It is easiest to assemble the frame pieces, square them up and hold them in place with bar clamps before drilling the 7/16" holes for the bolts to pass through. This way you will be drilling through all the boards at once and not have to worry about holes lining up later. Be sure to use a washer on each side of the bolt when bolting the pieces together.

Once the frame is bolted together, take the two 11.5" pieces, which are the top and bottom plates of the press, and counter sink a 3/4" hole in each corner about 3/4" from the edge. The countersink should be about 1/2" deep, then the remainder of the hole should be drilled with the 3/16" bit.

Now the two plates are placed as shown in Figure 3 and secured with the 1/4" lag screws with washers under the head. The side support legs are also held in place with 1/4" lag screws.

The remaining pieces of 4.5" wide boards can be used to stack up under the bottle jack for adjusting its height to fit whatever is being pressed. You will probably need at least four stacker boards, depending on what you are pressing. I prefer to cut them a little long and then notch the ends so that they lock onto the side timbers, as seen in Figure 1. This prevents them from sliding around or falling behind the press when setting it up.

Now go to an auto parts store and pick up a 12 ton bottle jack and you are ready to go!

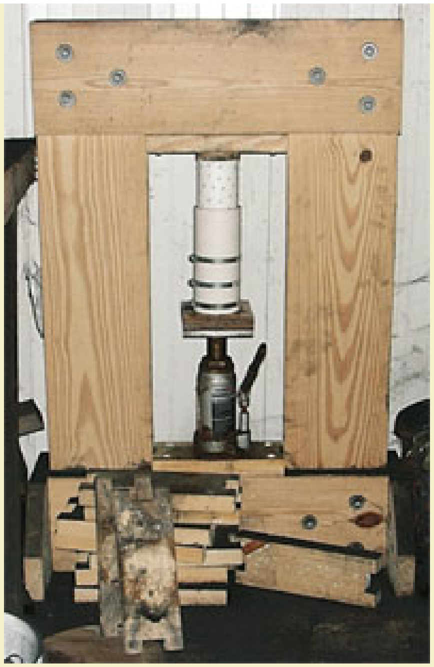


Figure 4: Pressing a 4" comet.

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Tool Tip... **Page 1**

Making Large Case Formers

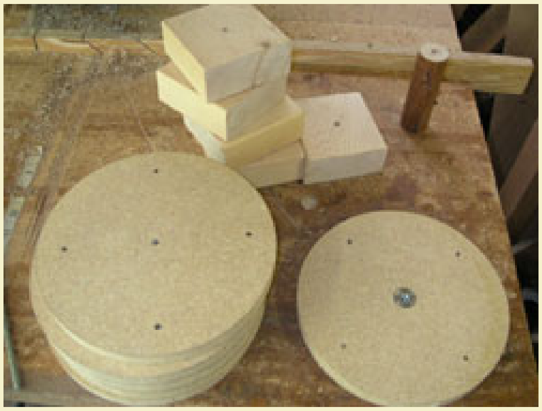

Figure 1: Case former components ready for assembly.

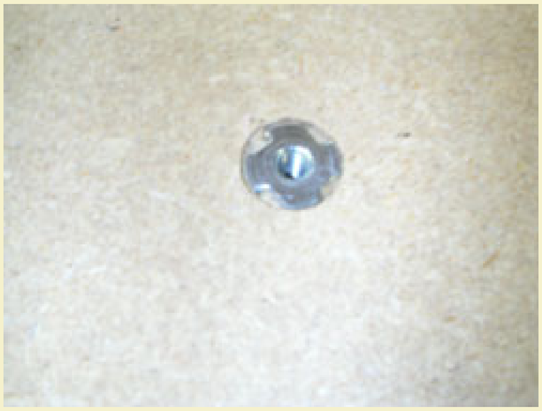

Figure 2: T-nut counter sunk into the center of the bottom disk.

Introduction:
Cylindrical case formers for rolling canister shells can be made in a variety of ways, limited only by the tools and materials available to the pyrotechnist. While good quality commercial case formers can sometimes be found made of wood, most hobbyists resort to making their own from whatever they can find. Smaller case formers can easily be made from sections of PVC or mortar tubes that have the desired O.D. For example, a 3" HDPE mortar with a 1/4" wall thickness is the correct size for making 4" shell case formers (which have a 3-1/2" diameter). This technique can be used with 4" and 5" mortars as well. Another method is to find a piece of pipe or even a spray can that is close to the desired O.D. and then build it up to the proper O.D. by wrapping turns of paper around it. I have seen wooden 6" case formers converted into 7" case formers by wrapping a 1/2" thick layer of newspaper around them. Case formers don't have to be pretty, they just have to be the right size!

Ideally a case former will be solid with a nice handle at one end to help remove the former from the finished case. The former should also have a ventilation cavity down the center so that suction forces do not prevent a tight fitting case from being removed. Good case formers will also have a slight taper toward the end opposite the handle so that the finished cases will slide off easily. Since some cases are rolled wet, a good former should also be waterproof and easily washed down without damaging the former.

A wood lathe can be used to easily create your own high quality case formers with only a minimal amount of turning skill. However, most consumer wood lathes don't have enough clearance to turn anything larger than a 6" case former. It is the larger case formers that prove the hardest to make, since it is harder to find large diameter pipes of the right size and building large formers up with paper tends to require a lot of paper.

The method of making case formers shown here is ideal for larger sized formers for shells 8" and larger. It is easy to produce any length and diameter that you desire, as well as taper it toward one end, without the need for a large lathe or special tools. The resulting former is smooth, washable, vented and yet not overly heavy the way a solid wooden former of the same size would be.

Construction
The case former shown here is made by building a support frame from wooden disks with spacers between them, then covering the

frame with aluminum flashing. The disks shown in Figure 1 were cut from particle board using a band saw, although a hand-held jig saw could just as easily be used. The center point of the disks must be accurately marked, so it is best to use a compass to draw the circles if possible so that you know where the exact center is. The disks can then be sanded smooth on the edges using a vertical sander to remove irregularities from the saw marks. However, the aluminum cover will tend to hide any defects that are not too extreme, so you can skip the sanding step if you don't have the tools to do it.

If you want a tapered former, which is recommended, you will need to cut the disks in a series that decreases in size from one to the next, then number them as you go so they can be kept in the proper order. The largest disk starts where the handle will attach, then each successive disk gets smaller. The O.D. doesn't need to decrease more than 1/8" between the smallest and largest disk, so the size difference between each disk will be very miniscule.

A 1/4" threaded rod will run through the center of the former, which will be used to hold everything together. Thus each disk needs a 1/4" or slightly larger hole drilled through the center point (except for the bottom disk, don't drill that one yet). You should also drill some ventilation holes through each disk as well in order to prevent the suction problem as previously mentioned. Four vent holes plus the center hole can be seen in the disks depicted in Figure 1.

The 1/4" threaded tie-rod will connect into the bottom disk using a T-nut that is counter sunk into the disk as seen in Figure 2. A T-nut is a threaded tube that has a flange on one end which keeps it from pulling through. The flange will be located on the outside face of the bottom disk. The flange needs to be counter-sunk so that it sits flush with the surface of the disk, so be sure to drill this larger hole first before drilling the smaller hole that the nut fits down into.

A block of 2x4 is used between each disk to create a 1-1/2" wide spacer. You will need to decide how long your case former should be, then figure out how many disks and blocks of wood to cut.

The final component is the wooden handle, which can be as simple as a wooden dowel rod with a hole drilled down the middle as seen in Figure 4. Due to the difficulty of drilling such a deep hole down the middle of the dowel rod, you may need to limit the length of the handle to 3-1/2" or 4".

Once you have all the components cut, the threaded rod is screwed into the bottom disk and the other pieces are threaded onto it. Wood glue is applied to the 2x4 spacers to help solidify the rammer once it is threaded together. Figure 3 shows how glued blocks are placed between the disks. The final disk is topped with the wooden handle, as seen in Figure 4. A washer and lock nut are firmly tightened down to clamp the whole assembly together.

Next you will need to cut a piece of aluminum roofing flashing so that it wraps one turn around the former, with about a 3/4" overlap where the pieces meet. The flashing can be bought in small rolls in almost any hardware store.

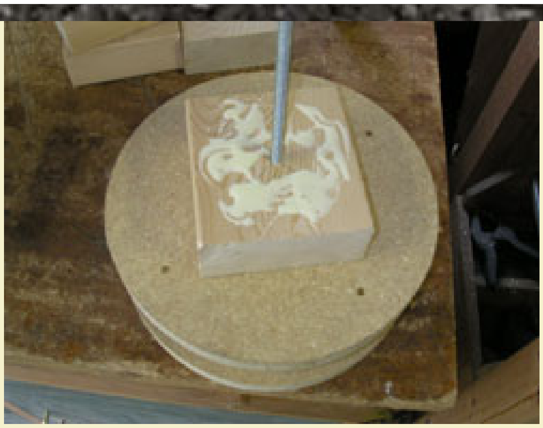
Figure 3: Threading pieces onto the center tie-rod.

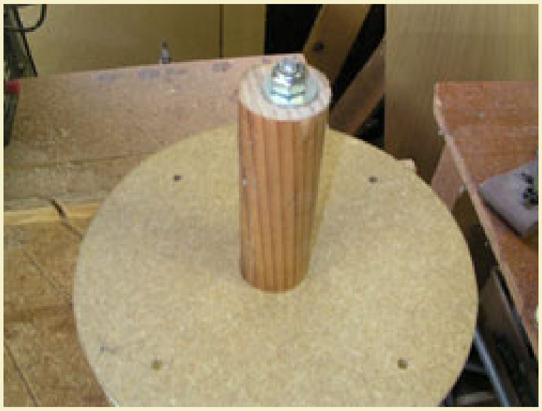
Figure 4: Washer and lock nut fastened at end of handle.

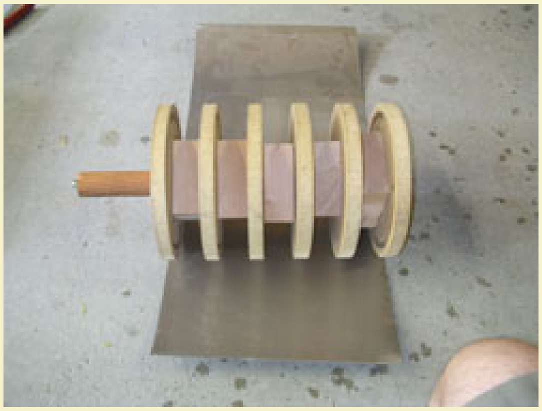
Figure 5: Aluminum flashing ready to fasten to frame.

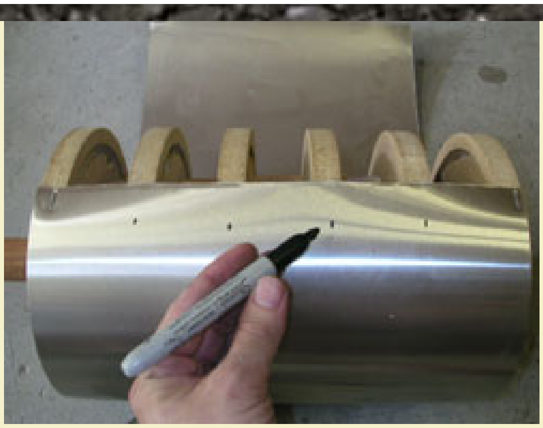
Figure 6: Marking the rib positions.

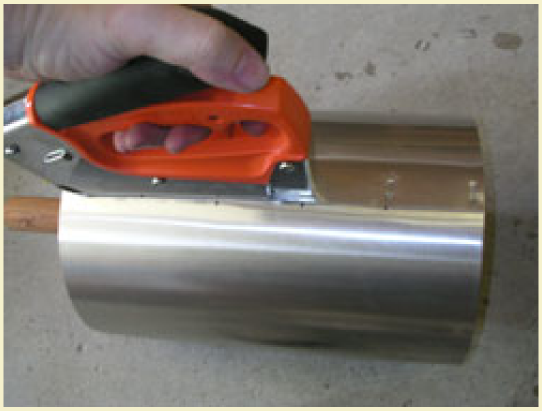
Figure 7: Securing the seam by stapling to the frame ribs.

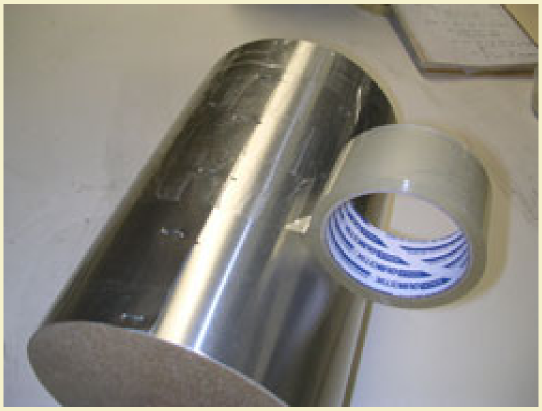
Figure 8: Final protective clear-coat using packing tape.

When you have a piece cut to the right size, secure the corners to the case former using a staple gun so that you can pull it tight around the frame. Figure 6 shows how you can use a marker to indicate where the internal ribs are located, which helps you shoot the staples into the correct spot once the frame is fully covered. Figure 7 shows the stapler used again to secure the overlapping seam to the wooden frame. The staples should be tapped down flush with the aluminum using a small hammer.

The final step is to wrap the former with clear packing tape so that the seam edge and staples will not be able to catch on the paper casings during use. The tape is started just behind the seam, then pulled very tight so that the edge of the flashing is securely held flat against the former. The tape band is run all the way around the former, then back over the seam once more for a double layer of protection. Parallel bands of the tape are applied next to each other as closely as possible, with care being taken not to overlap the edge of one band on top of the other. Care must also be taken to avoid getting wrinkles in the tape while applying it.

Note that the T-nut on the bottom prevents you from drilling out a spolette cavity for use when rolling cases with the spolette already glued into the end disk. Since the "upside down" method of shell building is not usually used on larger shells anyway, this limitation is pretty much a non-issue.

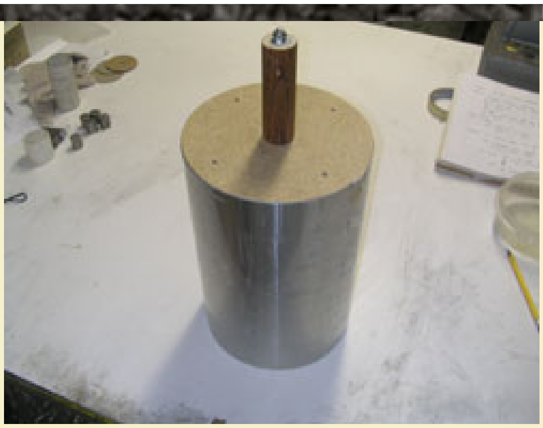

Figure 9: The finished case former.

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Tool Tip...

Page 1

Making End Disks

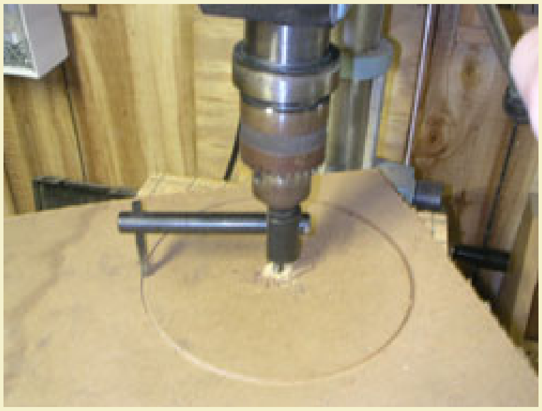

Figure 1: Cutting disks with an adjustable circle cutter.

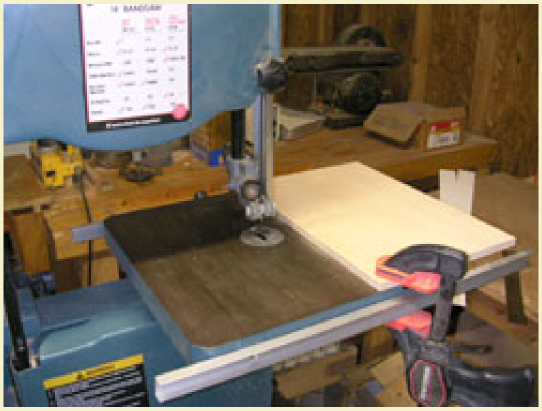

Figure 2: A center pin circle cutting jig clamped to a band saw table.

Introduction:
With commercial cardboard disks being fairly cheap and readily available in all the most common sizes, the thought of trying to make your own disks may seem like a misuse of valuable pyro time. However, there are occasions when you need odd sized disks or very large disks that are not easily found on the hobby supply market. For example, you may be making slightly undersized bottom shots so that when you roll the shell casing around them the resulting casing will have the correct inside diameter. Or you may be building odd sized canister shells like a Maltese 7" multi-break, which requires a 6-1/2" disk. Maybe you build one or two big 8" or 10" canister shells a year and don't want to order a bunch of disks in that large of a size. Then there's always the case where you decide to build something at the last minute and don't have time to wait for disks to show up in the mail (that would be me).

There are a few types of material sold in 8 by 4 foot sheets in most hardware stores that work well for making canister shell end disks. One type is a 1/8" thick cardboard insulation that has a shiny metallic surface on one side. While paste doesn't stick well to the aluminized surface, me and others have used disks made from this material in many shells without problems. It can be punched for smaller size disks and cut for larger disks without any problems, and the cost is cheap.

The second type of material that can be used is a composite wood fiber product called hardboard, which is also about 1/8" thick. This material has the combined properties of both paper and wood. It is more brittle than cardboard and can not be punched very cleanly, but holes can be drilled through it with much less trouble than with cardboard. Hardboard resists bending more than cardboard, but it does crack in half beyond a certain stress point.

Cutting the Disks:
One method of cutting disks from thin material is to

use an adjustable circle cutter, as seen in Figure 1. The advantage to this cutter is that it can be easily adjusted to cut any size circle you want. The disadvantage to this tool is that you can only cut up to about a 6-1/2" diameter circle, and it leaves a rather large hole in the center that is too big to use as a solid disk. The hole is also too big to accept Chinese time fuse, so you could only use the disks with spolettes. While this cutter makes perfectly round circles, it leaves an undesirable beveled edge on the disk. The paper tends to dull the cutting blade quickly, so frequent re-sharpening is another drawback.

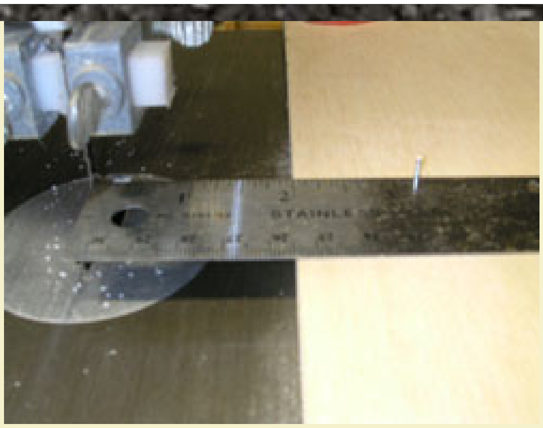

Figure 3: Setting the pin distance equal to the desired disk radius.

A much better way to cut circles is to use a center-pin type jig on a band saw, as seen in Figure 2. This jig is made by simply driving a small nail a few inches from the edge of a piece of scrap wood and cutting the head off to form a pivot point. Clamp this board to a band saw table so that the distance between the pin and the saw blade is equal to the radius of the disks you want to cut. Over this pin you will be placing square blanks with pivot holes drilled in the center, then rotating them into the saw blade to quickly produce your disks.

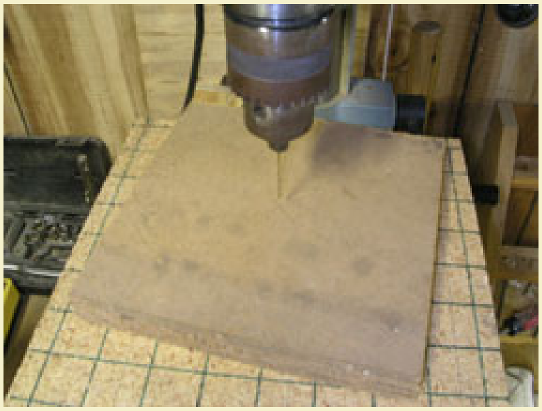

Figure 4: Drilling the center hole through a stack of disk blanks.

You will need a good way to cut up the large sheets of disk material into small squares equal to the diameter of the disks you are cutting (or just a hair larger). The hardboard actually cuts better on a saw than the cardboard, but a table saw or radial arm saw can make short work of either. Otherwise you can use a saber saw or other hand tool to rough out the squares. They do not have to be pretty, but make them slightly oversised if you are going to be sloppy about it.

Once you have a good many square blanks cut, mark the center point on one and place it on a stack of four of five blanks. Using a drill bit that is only slightly larger than the pivot pin on your jig, drill all the way through the center point on your stack of blanks. The top blank can be used as a template to drill out further stacks of blanks.

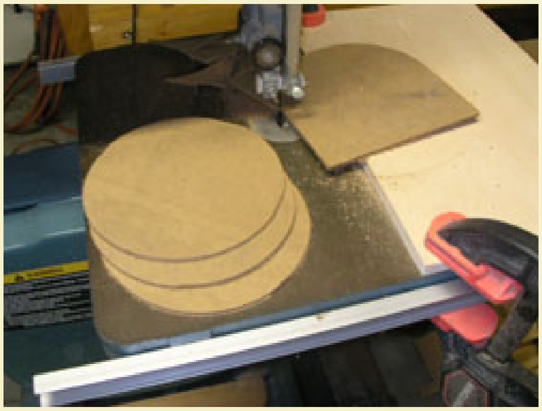

Figure 5: Cutting the circles by rotating the square blanks into the blade.

At this point cutting the final disks is quite easy. Simply place the blank onto the center pin and rotate it into the band saw blade until all the corners have been cut off, as seen in Figure 5. Be sure the blade tensioner is as low as possible on the blade, and make sure a fresh tension block is inserted into both sides. When spinning the material into the blade, it will want to bend out away from the disk, which will increase the cutting radius and make your disks a little oversized. Minimizing the length of unsupported blade will help reduce this, as will increasing the blade tension and using the widest blade possible.

The tiny center hole that results from this method actually comes in handy for punching holes in the disks later, allowing you to easily locate the exact center. The hole should be no larger than 1/16 of an inch, which will still allow you to use these as solid disks on the bottom of your shells as long as your paste wrap overlaps the center. If you are paranoid about potential gas leaks, just fill it with glue.

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Making End Disks...

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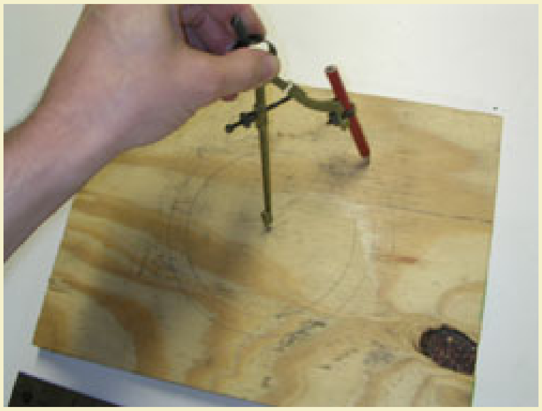

Figure 6: Using a compass to draw concentric disk templates.

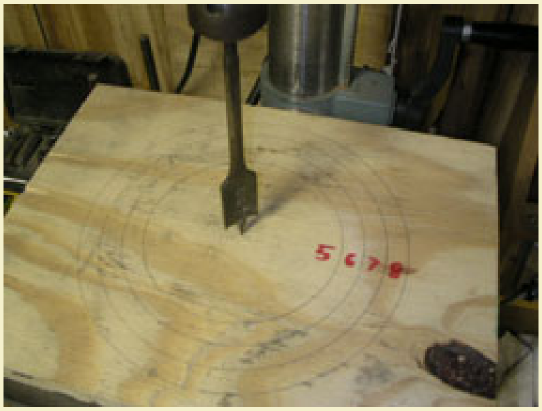

Figure 7: Centering the disk template guide uder the bit of a drill press.

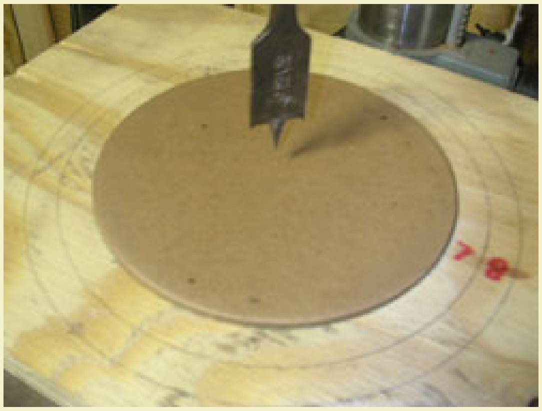

Figure 8: With power turned off, the bit is brought down to mark the center point on a

Center Punching Disks:
Even if you but your end disks from a supplier, you still usually have to punch spolette holes in them. Some people special order large quantities of disks with custom hole sizes already punched, but for the small scale hobbyist that is not really an option.

One issue that can be a pain about center punching commercial end disks is trying to get the hole located dead center. If you are off center, then your disks will not fit right over your spolette or your multi-breaks will not align with each other.

If you own a drill press, then the jig shown in Figure 6 and 7 will allow you to accurately mark the center point of various sized disks. On a scrap of wood, use a compass to draw concentric circles for the common disk sizes you use. These circles will serve as guides for positioning each disk.

To use the alignment jig, simply mount it on the drill press table so that the drill bit is aligned with the center point left by the compass. It is not really necessary to clamp the alignment board to the drill stand unless you plan to mark a lot of disks at once. It is a good idea to lock the adjustable table in place to keep it from moving back and forth though.

Once everything is aligned, simply position the disk to be marked in the corresponding circle and use the press to bring the bit down into the disk. There is no need to turn the drill on, just use a pointed bit such as a spade bit that will leave a small point in the paper, as seen in Figure 8.

Using a spade bit do drill spolette holes in your disks works pretty good when you are using hardboard, but does not work well at all with cardboard. Spade bits will cut the cardboard well enough, but the layered nature of paper results in thin disks splitting off and clogging up the blade so that it can't even make it through a 1/8" disk without stopping and cleaning it several times. Other types of drill bits will typically tear up the exit side of the disk, so that doesn't work well either.

The best way to make spolette holes in cardboard disks is with a hand punch. There are various styles of these available in sets of 1/8" increments. The one shown in Figure 9 came in a set with about 9 sizes that screw onto a single punch. Once nice feature about this punch is that it has a spring loaded center piece, which can be placed right on the center marks you made on your disks for precise disk.

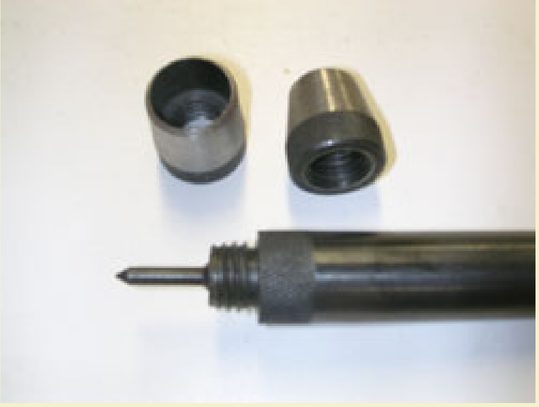

Figure 9: A hollow punch with spring loaded center pin to eject punched disks.

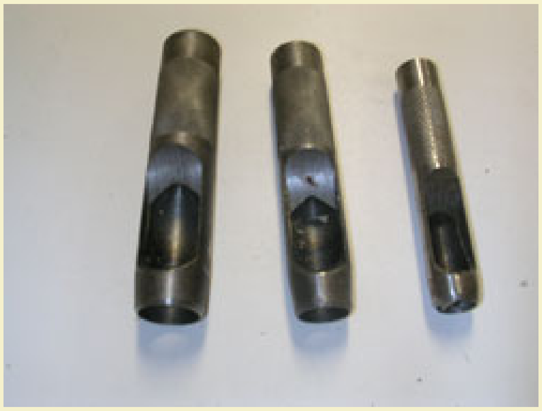

Figure 10: A set of one piece punches with fluted sides for disk removal.

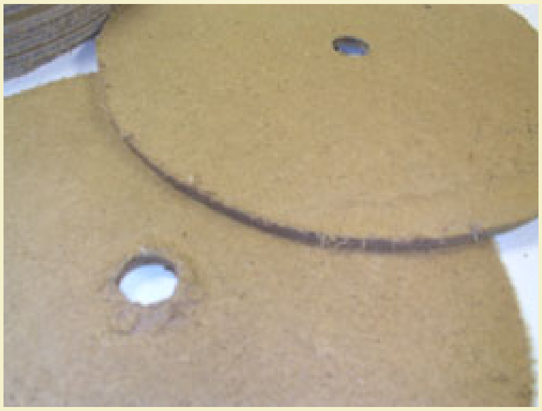

Figure 11: The deformed back-side of a punched hardboard disk compared with a drilled out disk.

positioning. The center pin actually recoils up into the rammer during the punch operation, then the spring forces it back out and, if you are lucky, ejects the punched piece from the hollow die. Half the time the spring is not strong enough to do the job unfortunately, and you have to unscrew the die and knock it out manually.

Figure 10 shows another style of hollow punch, these being a one-piece punch with a fluted opening that theoretically allows the punched material an escape route. The problem with these punches is that the inner cavity is not tapered enough, so the disks jam up inside to the point that you have to hammer them out with a ram rod.

Another type of punch, not shown here because they are more expensive and I don't own a set, is known as an "arch punch." These have a well designed taper that actually works as designed, allowing the disks to pop out the top as you use them. If you can afford them, these are the ones to get.

When using hardboard disks, it is actually easier to drill out the spolette holes than to punch them. This also results in a cleaner hole, as seen in Figure 11. Hardboard tends to bulge out on the exit side when punching, whereas drilling gives a clean hole on both sides.

When hand punching disks, you need to have a backing material that is not too soft but also allows the punch to cut into it. There is a type of hard rubber material that is made specifically for this, but a block of good hardwood like oak or maple works well too.

I find that a 4 lb mini sledge hammer works best when punching holes in disks, especially holes that are 5/8" or larger. I've had no luck getting an arbor press to do the job except on very thin material. Even then, the hammer method is still faster than a press.

Kraft disks are considerably harder to punch than chipboard disks, which is one reason I avoid them. Even with a 4 lb mini-sledge hammer, it can often take several blows to get a 5/8" hole punched in a virgin kraft end disk. Chipboard is much easier and does the job just fine as far as shell construction goes.

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Tool Tip...

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Hideaway Match Making Frame

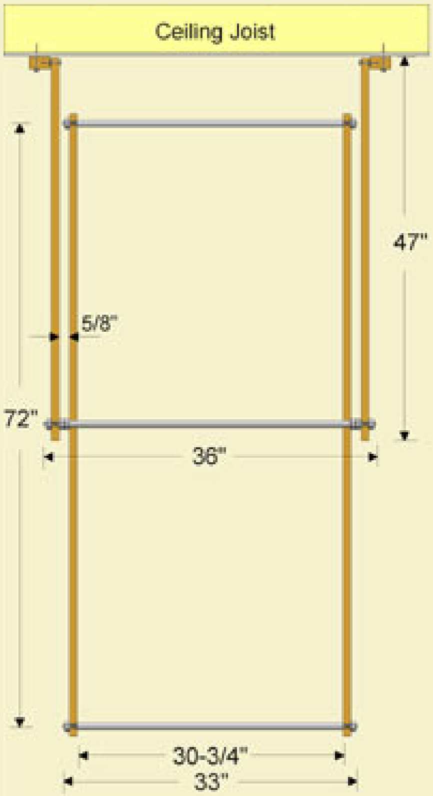

Figure 1: Match frame dimensions.

Introduction:
Match making frames are large rotating looms that are used to roll up and dry black match as it is manufactured. The larger the frame is, the more black match you will be able to produce at one time. The taller the frame is, the longer your lengths of continuous match will be. But lets face it, the last thing any of us need is another big contraption taking up valuable space in our pyro shops!

This simple match frame was designed for both maximum output as well as minimal space consumption. Many typical match frames rotate between two supports that rest on the ground. While this allows them to be moved around, they tend to take up a lot of space both during use and during storage. The design shown here is suspended from the ceiling of your shop or garage and folds up out of the way when not in use. You only need enough space to spin the frame when it is lowered down into it's operating position. When not in use, the frame is clamped flat against the ceiling where it will not get in the way.

The dimensions shown here will make six foot lengths of black match, producing about 300 feet of match when fully loaded. Most builders will only need to run one full batch per year to meet all their black match needs!

You can walk into almost any home improvement store and get all the parts you need to make this tool with only a minimal amount of labor in assembling it. No special tools or wood working skills are required.

Materials:

- (2) 30-3/4" long 1/2" O.D. aluminum tubing
- (1) 32-1/4" long 1/2" O.D. aluminum tubing
- (2) 33" long 3/8" threaded rod
- (1) 36" long 3/8" threaded rod
- (4) 3/8" hex nuts
- (6) 3/8" lock nuts
- (4) 3/8" washers
- (2) 76" long 1x2 lumber
- (2) 47" long 1x2 lumber
- (8) 1/4" washers
- (4) 3-1/2" long 1/4" lag screws
- (2) 2" long 1/4" lag screws
- (2) 4" long 1/4" lag screws

Tools:

- Electric Drill
- 1/2" and 3/8" drill bits
- Wood saw (power or hand)
- 3/8" wrench
- vice grips
- Hack saw

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Match Making Frame...

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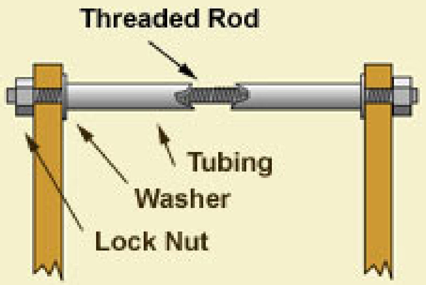

Figure 2: Tie rods holding frame together at both ends.

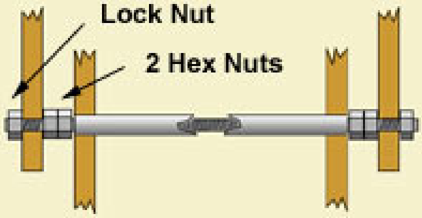

Figure 3: Center tie rod allows frame to pivot.

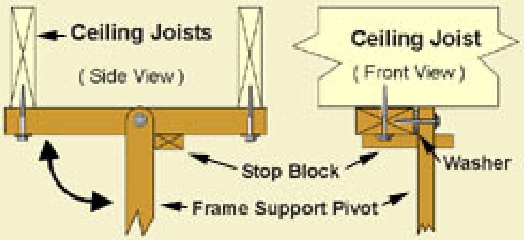

Figure 4: Details of swivel mount connected to ceiling.

Construction:
The first step is to get the frame assembled, which is fairly simple. Use a hacksaw to get the threaded rods and aluminum tubing cut to size, then cut the two 1x2s to a length of 76". A 3/8" hole is drilled on center one inch from each end of these boards, which is easiest to do by clamping them together and drilling through both of them at once. A 1/2" hole is drilled on center at the midpoint of the boards, which will be the pivot point.

The frame is now assembled by putting a lock nut onto one end of the two shorter pieces of threaded rod and feeding them both through the top and bottom of one frame board. A washer is now slipped onto each threaded rod, followed by the shorter 1/2" tubes, another washer, the other frame board and finally another lock nut. After the lock nuts are tightened snugly, both ends of the frame should look like Figure 2.

Before placing the second frame board onto the threaded rods as mentioned above, it is a good idea to insert the longer 1/2" tube into the center hole of one board so that it will fall into place when the two halves are put together. Otherwise the center tube will have to be slid into the side of the frame once it is assembled.

At this point the frame is complete. Now cut the other two 1x2s to a length of 47", which will be the suspension arms the frame hangs from. A 3/8" hole is drilled 1" from the end of each board, while a 1/4" hole is drilled through the other end of both boards. Again, stacking them and drilling both at once is the way to go. The ends of the boards with the 1/4" hole should be rounded off in a half circle so that it can rotate without the corners hitting the ceiling (see Figure 4).

Attach the suspension arms to the frame by inserting the 36" threaded rod through the center tube of the frame and spinning two hex nuts onto each end, which will serve as spacers between the frame and the suspension arms. The hex nuts should not contact the frame, leaving a small gap for the frame to spin. These nuts are tightened against each other using two wrenches so that they will not spin out of place. The end of the suspension arm boards with the 3/8" hole are now slipped onto the center rod and secured with a lock nut on each end. It may be necessary to hold the threaded rod with a pair of vice grips while spinning the first lock nut on. Be sure to select a spot where damage to the threads will not prevent the second lock not from going on. The lock nuts are tightened so that the suspension arm is pinned between the lock nut and the two hex nuts.

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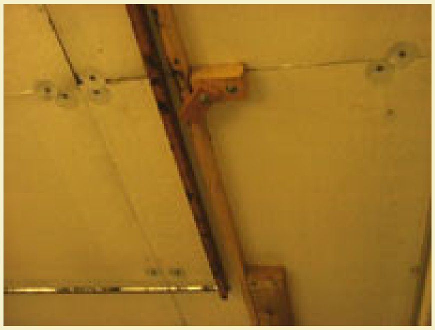

Figure 5: Clamps holding frame against the ceiling.

Next you will need to make your ceiling brackets that the frame will be hung from. This can simply be two segments of 2x4s that span the distance between two ceiling joists, as shown in Figure 4. They can be held in place with 1/4" lag screws that are long enough to go through the 2x4, any drywall that might be present and finally at least 1" into the joist. Make sure these brackets are placed so that there is room on the ceiling to accommodate the frame when it is folded up, as well as room to spin the frame when it is dropped down. Measure the distance between the outside edges of the suspension arms while they are attached to the center frame, then add 1/4" to determine the spacing required between the inside edges of your ceiling brackets.

With the ceiling brackets secured and parallel to each other, remove the suspension arms from the frame and fasten them to the center point of the ceiling brackets with a 1/4" lag screw. A washer is placed between the arm and the bracket as a spacer, and the lag screw is not tightened to the point of binding the arms.

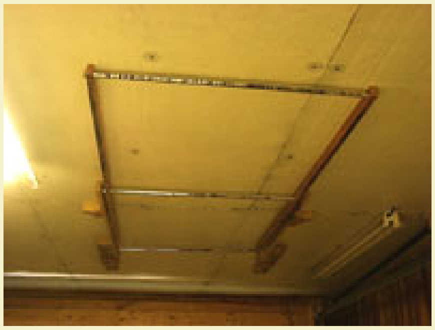

Figure 6: Match frame when not in use.

Once the arms are hanging in place, the frame is inserted back in its place and secured with the lock nuts again.

With the frame hanging straight down, fasten a stop block to the ceiling bracket just behind each arm on the side opposite to where you will be standing when operating the frame (see Figure 4). These blocks allow the frame to swing in one direction only, which helps to stabilize it when in use.

Finally you will need to make the clamps that hold the frame against the ceiling when not in use, as seen in Figure 5. These are made by attaching a small piece of 2x4 on each side of the suspension arms close to the middle of the frame. There must be a ceiling joist to anchor into, but get as close to the center as you can. Small tabs are loosely held in place by another 1/4" lag screw, such that the tabs can be rotated to clamp the frame against the ceiling and rotated out of the way to let the frame drop.

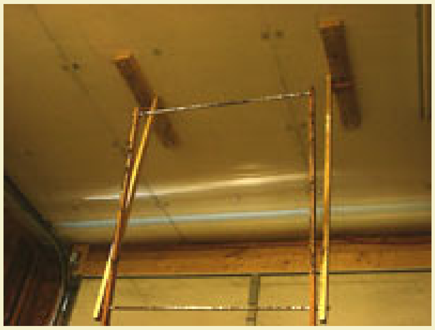

Figure 8: Frame folded down and ready for action.

The aluminum cross tubes that hold the match have the advantage of easy cleanup and the dried match does not stick to them easily. Best of all, your valuable floor space is preserved for other pyro contraptions!

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Volume 4, Issue 5

Tool Tip...

Page 1

Making Screens

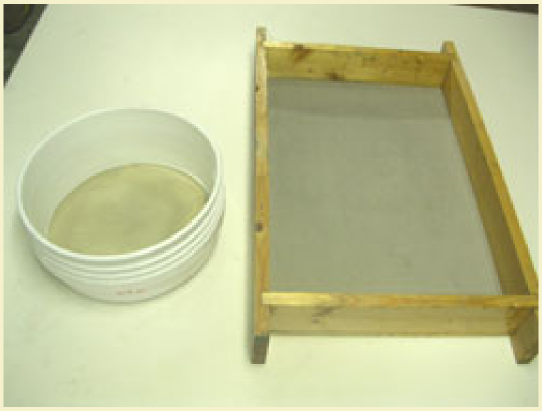

Figure 1: Two types of screens described here.

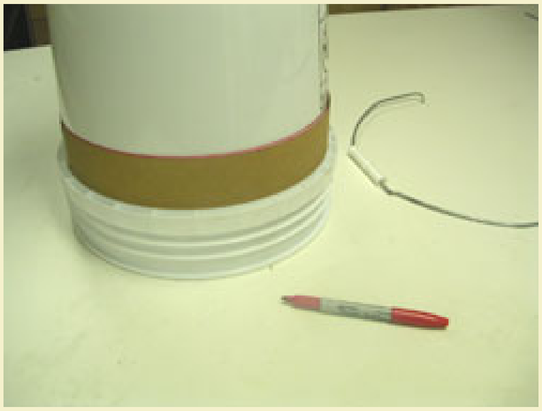

Figure 2: Using a band of paper as a guide when drawing the cutoff line.

Introduction:
One can not get very far in pyrotechnics manufacture without a good set of mixing screens. The most effective way to integrate the various powdered chemicals in a pyrotechnic formula is by passing them repeatedly through a metal wire screen. This not only breaks up clumps frequently found in the chemicals, it also helps the individual chemicals become intimately combined into a homogeneous mixture.

Mixing screens are typically made from a non sparking metal that is resistant to corrosion, such as brass, aluminum or stainless steel. The stainless screens have the best corrosion resistance and also tend to deform less than the brass variety.

The mesh size of the screen will depend on what it is used for. For mixing purposes, screens in the 20 to 30 mesh size work well. This is large enough to allow an easy flow through the screen without clogging, while still small enough to break up clumps into small enough particles. Most chemicals are already pulverized into a fine particle size and the clumps are usually groups of small particles rather than solid chunks. Screens above 50 mesh start to clog when passing certain chemicals, and the mixing process goes much slower. The screens described in this article use a 24 mesh brass screen, which is good for most general mixing purposes.

It is sometimes necessary to have larger mesh sizes for the purpose of extracting large particles from a mixed range of particles. This is most commonly used for sifting out specific mesh ranges of charcoal or aluminum flake required for long tails or other special effects. It is a good idea to examine the formulas you plan to use and pick three or four mesh sizes that they have in common. A screen set might have something like a 10 m, 15 m, 20 m and 30 m. The sizes do not need to be exact in most cases, for example using a 24 m where 20 m is called for. If you make your own BP, you will also need a set of screens for giving you the powder grain sizes you

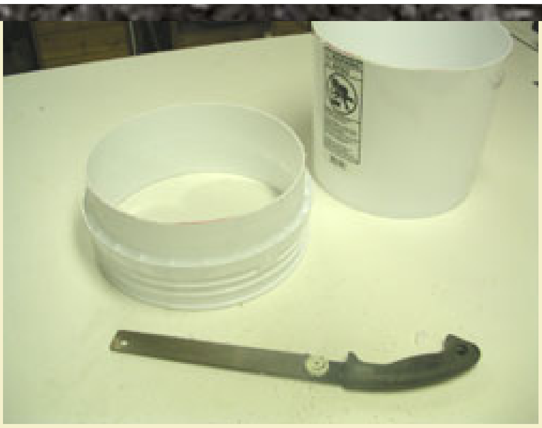

Figure 3: Using a pull saw to cut the bucket in half.

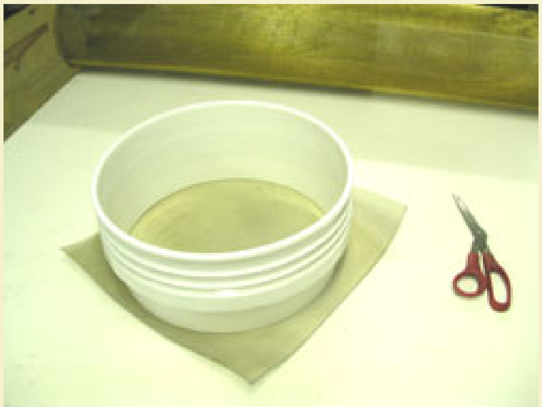

Figure 4: Cutting the screen a bit larger than the bucket.

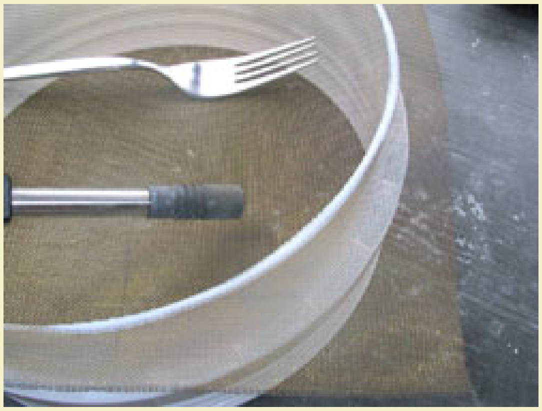

Figure 5: Using a blowtorch to heat the screen and sink it into molten plastic.

want to make. It is not uncommon for a pyro to accumulate over a half dozen screens for various tasks.

Two of the most common screen construction techniques are described here, as well as a few pictures of some uncommon techniques.

Bucket Screen:
This type of screen is the most elegant, rugged, easy to make and easy to use of any I have seen. I don't know who to credit for coming up with this idea, but I consider it one of the classic "best practices" pyro tool techniques.

The idea is quite simple: cut the top off a 5 gallon bucket and use heat to melt a screen solidly into the plastic edges. The advantage to bucket screens is that they are cheap to make, require no special tools, can be made in 15 minutes, can nest inside of each other for easy storage, they are water proof and best of all, they fit into the top of another 5 gallon bucket to catch the screened material during use! This feature eliminates the need to make a seperate screening box, which is required for the wooden screen shown in figure 1.

The melted plastic holds the screen so well that deformation from pushing against the screen is much less than wooden box screens. The only down side is that they hold less volume than the larger wood screens, and the working angle when screening is a little steeper and not as comfortable as with a larger screen. They still have plenty of capacity for mixing five and ten pound batches though, more than most hobbyists need in many cases.

The first step is to remove the metal handle from the bucket and then cut about 4 inches down from the top. Do not make it too deep or you will have a hard time getting your hand down into it when mixing. Figure 2 shows how a band of paper can be used as a guide when marking the cut line, thus avoiding the potential for an uneven cut. Figure 3 shows a thin pull saw that makes cutting the bucket just as quick and easy as attempting to use a jig saw or other power tool. The bottom of the bucket can also be put to good use as a girandola frame as shown here.

Next you will want to prepare a square sheet of screen that has at least an inch of overhang around the edges. The screen shown here is 24 mesh brass cut from a roll, but any type of screen can be used including window screen (although window screen is a little too coarse for good mixing).

Working out doors, use a blow torch to heat the screen and the bucket edge at the same time, allowing the screen to push down into the melted plastic so that it becomes fully submerged. The plastic should completely seal off the screen as seen in Figure 6. It helps to work in sections and let them solidify before moving to the next section. This lets you pull the screen tight as you work without pulling it out of the soft plastic. Be careful not to grab the screen with your fingers near the hot spots, rather use a fork or other object for pushing on the screen when sinking it. Otherwise you will have a grid pattern burned into your finger like I have right now. Ouch!

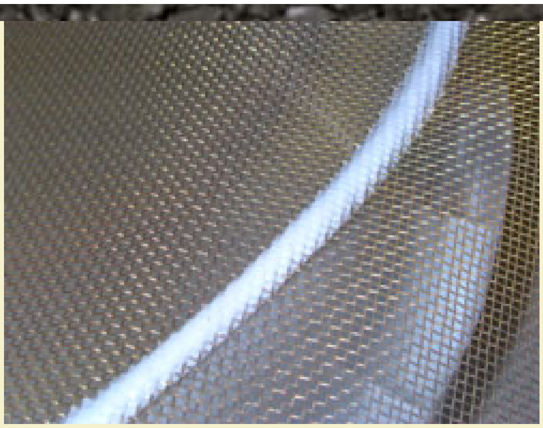

Figure 6: A closeup of the embedded screen.

Once the screen is completely melted in place, scissors or a knife can be used to trim it flush with the edge of the bucket. You will also need to sand it further to get rid of all the sharp little wires left sticking out, otherwise you will pay the price later with stuck fingers! Figure 7 shows the trimmed and sanded edge. This completes your screen and it is ready for use.

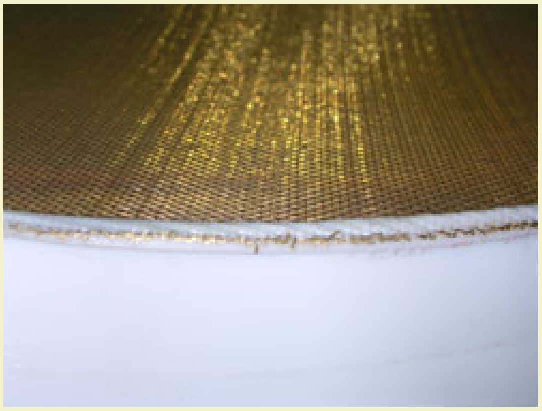

Figure 7: Closeup of screen edge after trimming and sanding.

Usage Notes:
Figure 8 shows how this bucket screen conveniently fits into another 5 gallon catch-bucket when screening. It helps to have two 5 gallon buckets on hand when screening, such that you are feeding the screen from one bucket while the other is used to catch the screened material. You then move the screen to the other bucket when it is empty and feed from the previous catch bucket for the next screening.

More...

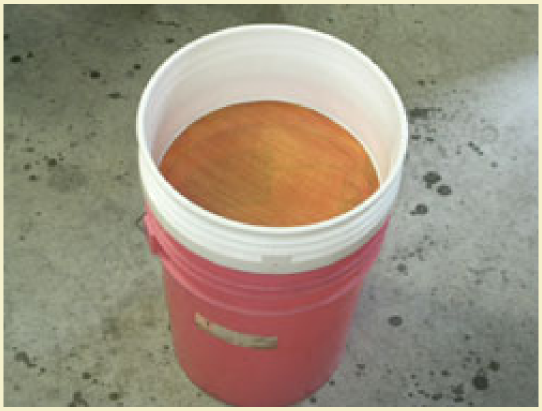

Figure 8: Screen nests conveniently into another 5 gallon catch-bucket when mixing.

Mixing Screens...

Page 2

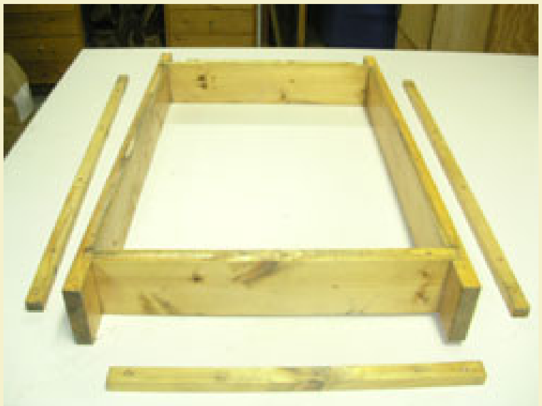

Figure 9: A simple box screen ready to be assembled.

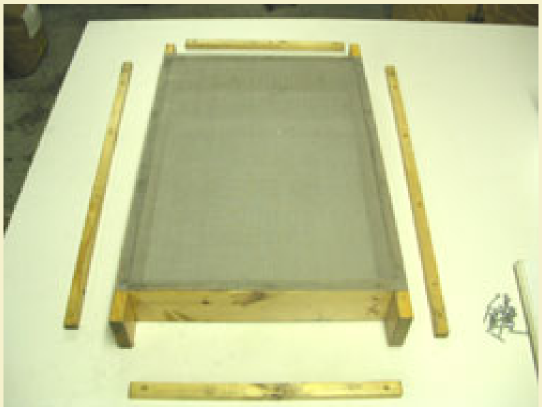

Figure 10: The screen in place (already trimmed).

Wood Box Screens:
This type of screen is probably more commonly used in industry for its higher capacity, but it is not all that difficult to build one. The basic concept is a wooden box frame with a screen attached to the bottom of it. There are various ways to make these, depending on what type of tools you have. I make all my screen frames using interlocking "dado" joints to make alignment easy and eliminate the need for using screws or nails. Dove-tail joints would be even stronger and cleaner, but considerably more trouble.

Figure 9 shows a typical frame made from 1x4 pine boards. Before the board is cut into the four segments, a 1/2" strip is ripped from one edge, which will be used to make the clamping bars that hold the screen to the bottom. This gives you a 3" wide board to use for the box, which is deep enough to easily mix five to ten pound batches (depending on the comp density). Two 26" long boards are cut for the long sides, then two 15-1/4" boards for the short sides. A 3/8" deep dado channel is cut 1-3/4" in from each end of the 26" boards. The short sides are then fit into these channels and the frame is glued together and clamped until dry.

The 1/2" strip is then cut into two 26" long strips and two 14-1/2" long strips. I use 1-1/4" long #6 wood screws to hold these clamps to the box frame, with three on the short side and six on the long sides. The clamps are put in position on the edges of the screen box and pre-drilled with #6 countersink bits, fastening each screw as you go to keep things from sliding out of position. The screws are then removed and the clamp bars are set to the sides of the frame prior to installing the screen.

All the parts are ready for assembly in Figure 9. At this point you need to water proof all the pieces before installing the screen, because your screens will be frequently hosed off when cleaning them. Polyurethane or clear acrylic spray can be used for this purpose as long as the screens are not submerged in water for any length of time. Any kind of outdoor paint will work as well.

Once water proofed, the frame is ready for installing the screen. The screen material is laid over the box and rough cut with a few inches of overhang, which will be trimmed off later. Figure 10 shows a piece that has already been trimmed because I took apart an existing screen, but normally the screen would be oversized to allow for exact trimming after assembly.

Start by screwing one of the short bars completely down over the screen on one end. This allows you to pull the screen tight while clamping the remaining bars. Screw down the two long side bars next, making sure to pull the screen tight the whole time. The remaining short bar is last to be screwed down.

Any overhanging screen is now trimmed with a utility knife. Be sure to angle the blade up under the wood to trim the screen off as close as possible, otherwise you will have pointy wires sticking out that will stick your fingers later. Figure 11 shows the finished screen after trimming.

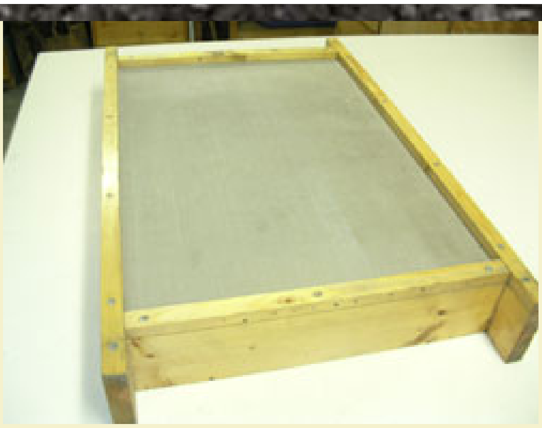

Figure 11: Clamp strips used to fasten screen to frame.

In order to use this type of screen, you will need to build a screen box to hold it up off the working surface. Figure 12 shows a simple screen box built to fit this frame. The box is constructed to hold a 16" wide screen about 6" above the table. Six inches is about the minimum height you would want, otherwise large batches of comp will pile up and touch the screen during use. Taller boxes also allow better mixing during screening, since there is a longer distance for the screened material to fall and intermix on the way down.

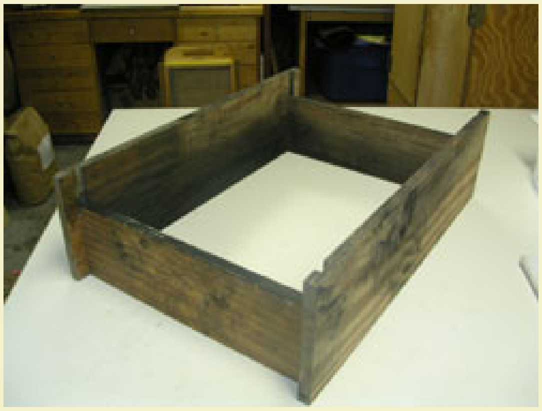

Figure 12: A mixing box used to support the screen during use.

Figure 13 shows the screen placed on top of the mixing box. Note the two shorter sides of the box allow the screen to nest inside of two taller walls, which keep it from sliding off. An alternate method is to build a box with all four walls the same height, then fasten an inner shelf along the top edge to support a screen designed to fit snugly inside the box. You want to avoid air gaps between the screen and the box walls, otherwise a lot of dust will come up through the cracks.

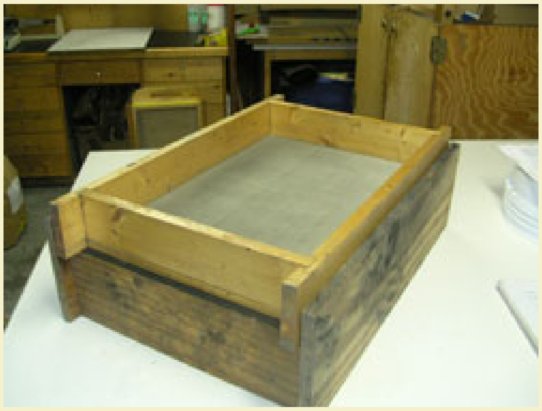

Figure 13: Screen in place atop the mixing box.

Fancy Screens:
Figure 14 and 15 shows a rather fancy screen that is perhaps more trouble than it is worth for most people to make. The screen has a rounded bottom, with the idea of keeping the material to be screened at the center of the screen. Because of this rounded bottom, it can not sit on the screen box directly and special rails had to be installed on the sides, which rest on the screen box during use. This screen also features dove-tail joints for a strong box, oak clamping bars that are thin enough to be bent over the rounded bottom, and a handle for sliding the screen back and forth and banging it up and down to dislodge clogged screen holes while mixing.

Figure 16 shows an even more elaborate screen system. A desktop with a hole that drops down into a removable drawer serves as a built-in screen box. Screens are inserted as seen in Figure 17, then the material is collected in the paper lined drawer. The drawer is then removed and replaced with another identical drawer from two rows of drawers on each side. This concept was taken from commercial industry, but is really not that practical for hobby pyro. The screens shown here really do not have a good frame for containing much powder, and the capacity is rather small. But the real problem is that all screening should be done out doors, and lugging a large desk outside just to mix chemicals is not very desirable! This setup is really more practical for small scale indoor chemistry experiments using a vented hood above the screen hole, and was designed for such operations.

There are dozens of ways to make screens, and some people even use simple kitchen sieves to do their mixing. The bucket screen and the wood frame screen illustrate the two most common types and give a good starting point for fabricating your own screens. Obtaining the screen material itself is usually the hardest task. Screen material can often be found at hobby pyro conventions, and McMaster Carr is a good place to find a large variety of mail-order screens online. I prefer the milling grade stainless steel screens, which are located in the Woven Wire Cloth catagory. Avoid screens made from wires much thicker than .015, since powder has a hard time dropping through the thicker screens.

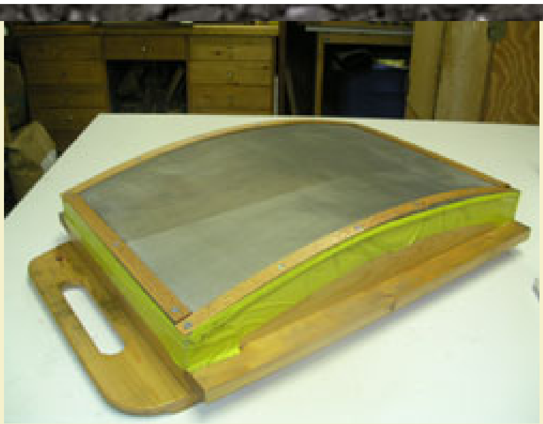
Figure 14: A fancier screen with a rounded bottom and handle.

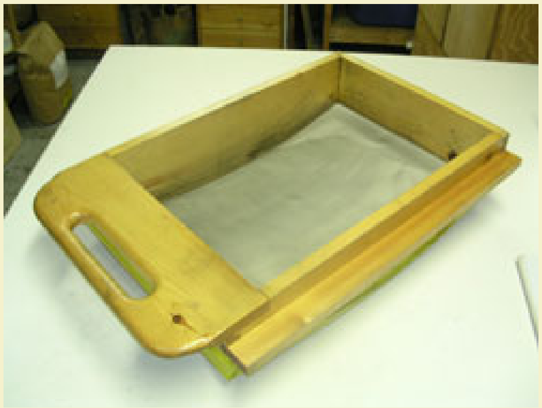
Figure 15: Top view of deluxe screen.

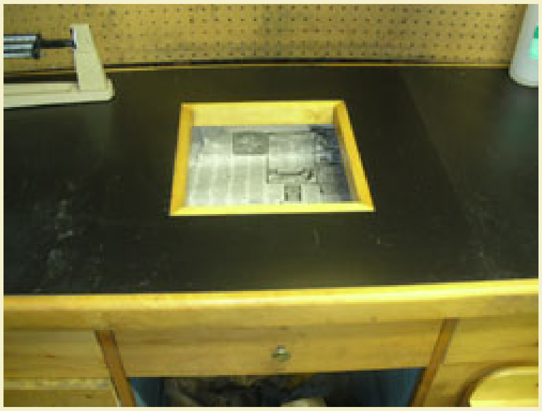
Figure 16: A screening bench that uses a drawer for the screen box.

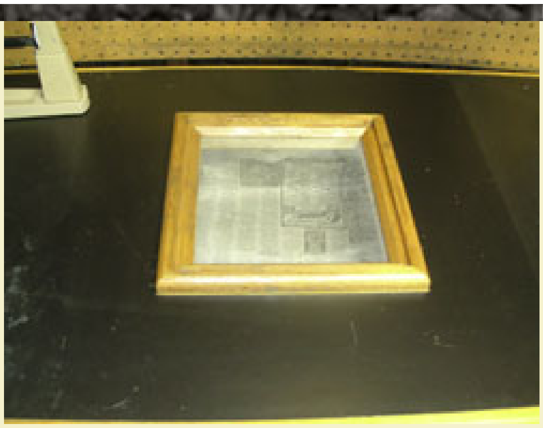

Figure 17: Interchangeable screens drop into the table top.

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Volume 3, Issue 8

Tool Tip... **Page 1**

Multi-Puck Powder Die

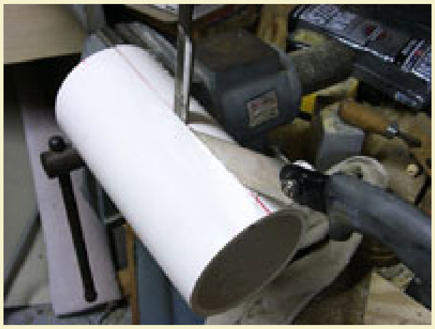

Figure 1: Splitting a segment of 4" PVC.

Introduction:
A powder die is basically a sleeve and piston arrangement that is used to compress milled black powder into hard, dense cylinders often called "pucks." These pucks are later granulated to make black powder grains of various sizes, a process described here.

While many black powder hobbyists seem to be pressing one puck at a time, the powder die shown here is designed to press up to 8 or 9 3/8" thick pucks at a time. When pressing many pucks at once, a 12 ton hydraulic press is required. However, the same die can be used to press single pucks with less powerful hydraulic jacks if a longer rammer is made.

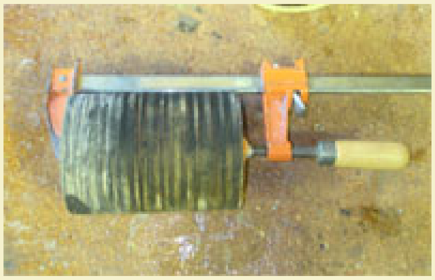

Figure 2: Laminating plywood disks to form the rammer.

Construction:
The sleeve used for this project is a segment of 4" PVC that is 7 or 8 inches long. The wall thickness should be about 1/4" to handle the pressure generated. The sleeve will also need to be split down one side to make removal of the pressed powder possible. This is easily done by clamping the pipe in a vice and using a Japanese type pull saw to cut along a straight guideline as shown in Figure 1. The pipe will want to collapse in on the cut as you get near the end, so using a chisel or screwdriver to hold it open will help prevent your saw from binding.

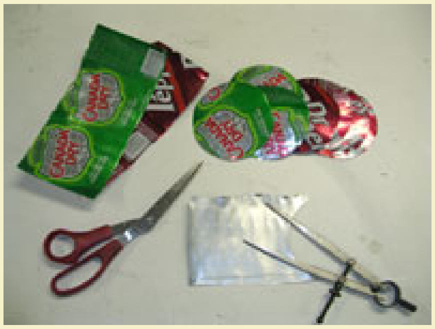

Figure 3: Making separation disks from soda cans.

Using the thin pull saw or other hand saw to cut the pipe is the easiest and safest way to make the slit, as the binding problem can be dangerous when using power saws (pipe grabs blade, blade throws pipe!). If you want to use a power saw, you will need to make two cuts down the length of the pipe. For the first cut, set the depth of cut to slightly less than the wall thickness of the pipe and make a cut down one side of the pipe. Now set the saw to cut all the way through and make another cut down the opposite side of the pipe. The first cut will have created a "hinge" which keeps the pipe from binding on the blade.

The rammer can be made as done for the 4" comet pump shown here (minus the center hole), but an alternative method is to simply glue together a bunch of 3/4" thick plywood disks as shown in Figure 2. First measure the I.D. of your sleeve after slotting the side, then make the disks about 1/8" less in diameter. Wood glue is placed between each disk and then the lot of them are clamped together using a bar clamp. The rammer should be at least 6" long, otherwise make it as long as the PVC sleeve. When dry, a belt sander or lathe can be used to trim up any uneven edges where the disks didn't quite line up. The finished rammer should be at least 3-3/4" diameter. Sealing the finished rammer with epoxy or polyurethane will help prevent water carrying saturated nitrates from absorbing into the rammer during use.

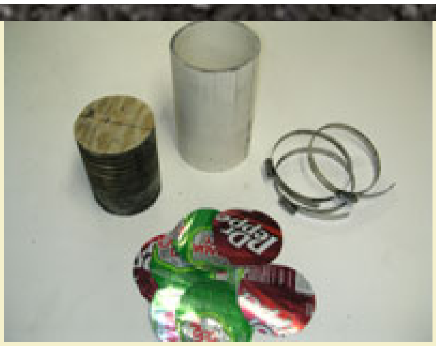
Figure 4: Powder die components.

When pressing more than one puck at a time, it is necessary to insert separation disks between the powder layers so that the pucks can be separated after pressing. These are best made from soda cans, since the coating on the thin aluminum used in cans is very resistant to adhesion or corrosion from the nitrates. Figure 3 shows a scribe being used to make circles on sheets of the soda can metal, which was cut using regular scissors. The diameter of the disks should be very close to the I.D. of the sleeve, such that when you drop one into the sleeve it slowly floats to the bottom without binding. If the disks are cut too small, then powder will bind around the edges and make the pucks difficult to separate after pressing. You will get two disks per can, and 12 disks should be all you need.

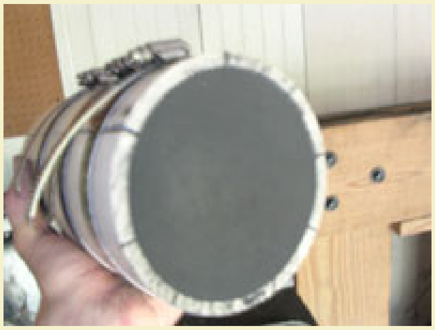
Figure 5: Slots on sleeve bottom to drain water.

You will need to obtain at least three pipe clamps that fit around your sleeve, as seen in Figure 4. These clamps will be evenly spaced apart along the sleeve during pressing, and tightened down to prevent the split sleeve from opening or bulging during pressing.

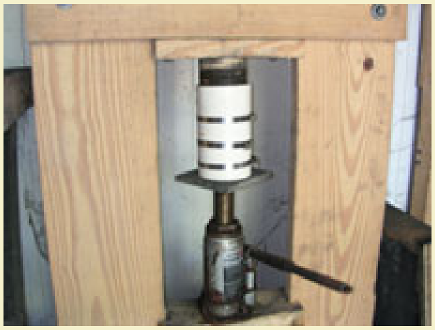
Figure 6: Powder die in operation.

Figure 5 shows the bottom of the sleeve, which has been slotted around the perimeter to allow water to seep out around the edges during pressing.

Lastly you will need a thick aluminum plate to use as the bottom for the sleeve to sit on when pressing. A small scrap of 1/2" thick aluminum scrap can usually be found in metal scrap yards and will do the job nicely.

The die is charged by first tightening the pipe clamps and placing the sleeve on the bottom plate. A powder charge of about 1 cup is added, followed by a disk. This powder/disk sequence is repeated, manually pressing with the rammer every four increments. When fully charged to within an inch or two from the top (after manually pressing), the die is charged and ready for pressing.

For more information regarding the use of this die for making black powder, click here.

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Tool Tip... **Page 1**

Paper Cutting Station

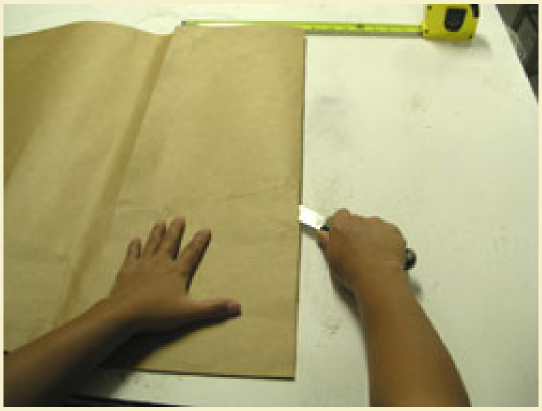

Figure 1: Cutting paper the traditional way.

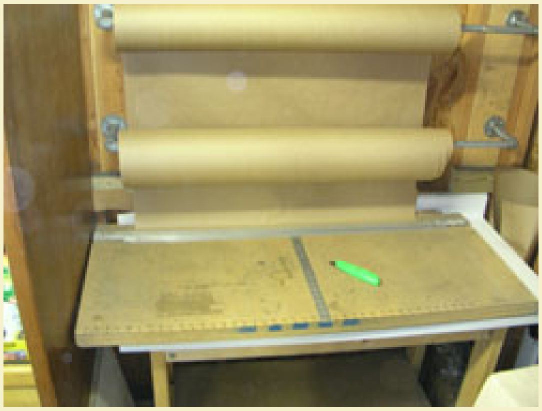

Figure 2: A cutting station that works with both rolls and sheets.

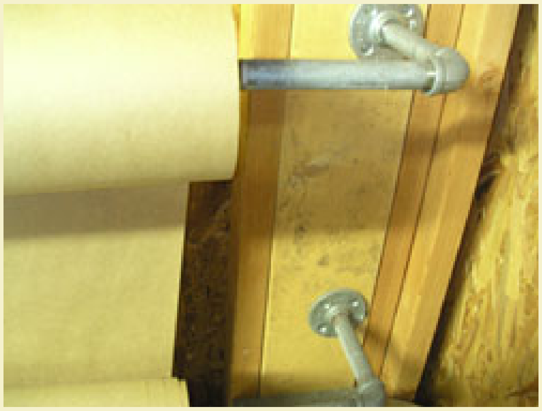

Figure 3: Pipe fittings used to hang paper rolls.

Introduction:
Cutting paper is a task so routine and repetitive in pyro manufacture that any improvement in efficiently will pay for itself in a short time. The task of cutting paper is so commonplace that some people may not give it much thought, but once you work with the paper cutting jig shown here you will wonder how you ever got along without it.

The traditional method of cutting paper is shown in Figure 1, which is used primarily for cutting sheets of paper. The sheet is folded over on itself a measured distance, then a sharp knife is used to cut down the fold. The advantage of this method is that you can cut several sheets of paper at one time. However, the disadvantage is that it is difficult to cut small strips this way, the cuts are hard to keep straight and the procedure does not lend itself to cutting paper from rolls.

Using paper from rolls results in less waste and is preferred by many hobbyists. Rolls are also easier to store than large sheets of kraft, which must be stored flat in a heavy stack that is also difficult to move around. Those who prefer working with sheets, usually for the advantage of being able to cut many pieces in one pass, must build special shelving that is large enough to hold several separate stacks of the various weights they work with.

The paper cutting station shown in Figure 2 works with both rolls and sheets, and takes up a minimal amount of shop space. The rig is designed to insure that cuts are parallel, that the paper is held down to prevent sliding or ripping during cutting, and that strips of any size can be easily and quickly cut. A built in length gauge allows for easy measurements of up to 18" wide strips without the need of holding a ruler during the process.

The concept is quite simple: A thin aluminum channel serves as a guide for the knife blade while cutting. The paper is fed under a hold-down bar and pulled out over a measuring table that has parallel lines marked out every inch. A central ruler allows finer measurements with a 1/4" accuracy. The paper is pulled out to the proper mark, then the knife is run down the slot as seen in Figure 5.

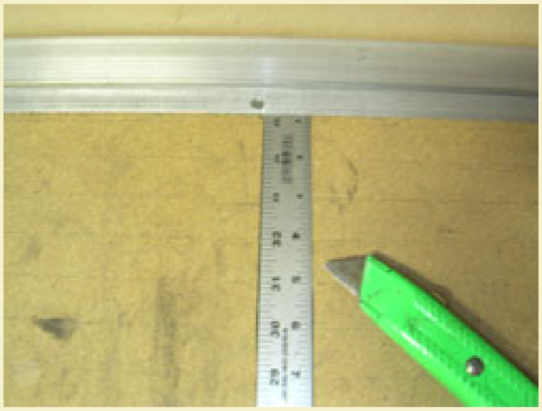

Figure 4: Closeup of the cutting slot and length scale.

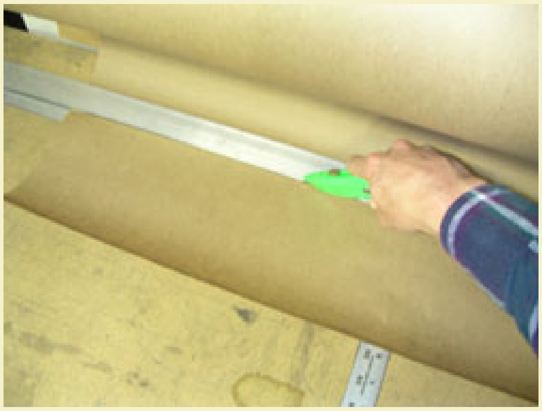

Figure 5: Cutting from a roll using a utility knife.

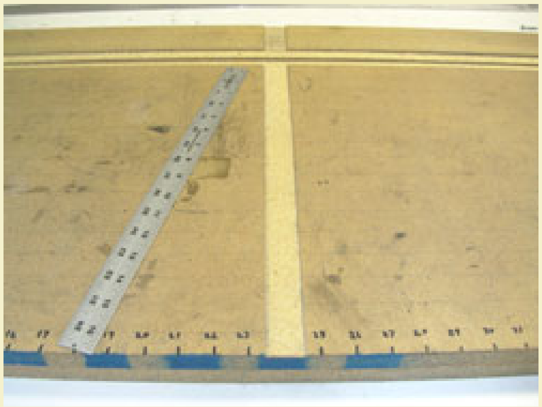

Figure 6: Base board assembled with channels cut for inlays.

The cutting block is ideally located under large rolls of paper stacked above one another as seen in Figure 2. Half inch plumbing pipe fixed to a sturdy wall mount is ideal for holding heavy rolls of kraft paper. The sheets are easily slipped under the aluminum hold-down bar and pulled as you cut.

The cutter also works with sheets of kraft, chipboard and posterboard, as one or more sheets can be fed under the hold-down bar and cut in the same way. The 1/8" thick aluminum bar is flexible enough to pull up with your fingers when sliding paper under it, yet still does a good job at keeping the paper from sliding or binding up on the knife blade when cutting.

Materials:

(x) 4 ft long 1/2" threaded plumbing pipe
(2x) 3-1/2 in. long 1/2" threaded plumbing pipe
(2x) 1/2" threaded flange mount
(1) 4 ft x 20-1/2" 3/4" particle board
(1) 4 ft x 16-1/2" 3/4" particle board
(1) 4 ft x 3-1/2" 3/4" particle board
(1) 4 ft long 1-1/2" x 1/8" thick aluminum bar stock
(2) 4 ft long 3/4" aluminum angle stock
(6) 3/4" long #6 wood screws
(4) 1" long #6 wood screws
(12) 1-1/4" long #6 wood screws

Construction:

The cutting block is constructed from two sheets of 3/4" particle board to provide a heavy base that is resistant to sliding around as you cut. The three pieces are ripped from a standard 4 ft wide sheet. The dimensions are designed so that the unit fits onto a standard piece of 22" kitchen countertop with rear spash gaurd. The 20-1/2" wide piece is used as the bottom piece, then the two top pieces are aligned with the front and back edge such that a small 3/8" gap is between them.

The top edges of the boards on each side of the channel must be rabbited to form a 1/8" deep inlay so the angled aluminum used to line the channel will seat flush with the cutting board surface. The rabbit cut can be made before the pieces are assembled, or you can cut them both at once after assembly if you have a dado blade that goes out to 1-3/8" wide.

The two top boards are held down to the bottom base board with the 1-1/4" wood screws, screwed from the bottom to keep the cutting surface clean. Figure 6 shows the slotted base ready for metal inlays. A central slot has also been cut to allow a section of metal yard stick to seat flush with the

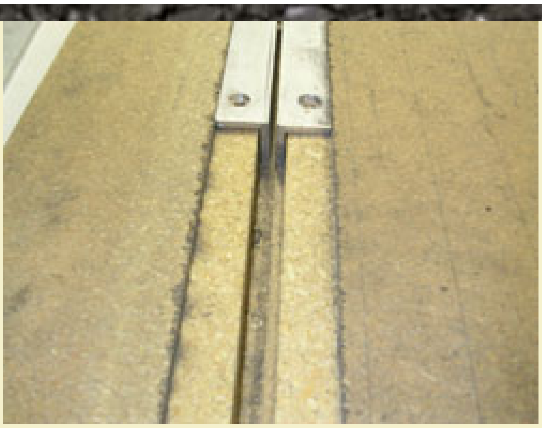

Figure 7: Closeup of angle aluminum fitted into cutting channel.

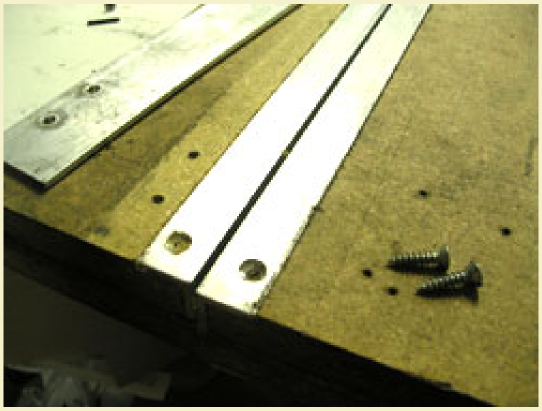

Figure 8: Attaching hold-down bar behind cutting slot.

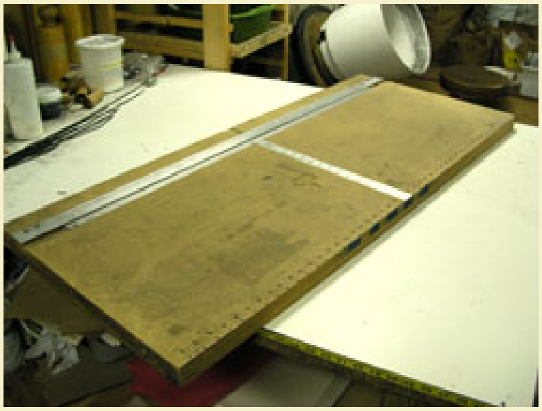

Figure 9: Finished cutting board.

cutting surface. This is a fancy extra and is not really necessary, as you could also just draw a ruler on your table using a permanent marker. Whatever method you use, the scale must measure from the center of the cutting slot.

Figure 7 and 8 shows the two pieces of angle aluminum being installed into the slot. The screw holes must be countersunk into the aluminum so that the taper head screws used to hold it down will sit flush with the surface and not catch the paper as it passes over them. The screws that hold down the 1-1/2" wide hold-down bar must be no more than a few inches from the edge, giving you maximum area for sliding sheets under it. Most sheets and rolls will not be wider than 36" , so you have a good 12" of margin to play with.

Figure 9 shows the finished cutting board. You will want to mark a series of lines parallel to the cutting slot, measured out at one inch intervals from the center of the slot. The central measuring scale is used to determine the desired width of your paper strips, while the parallel lines are used to insure an even width across the cut. It is pretty easy to eye-ball dimensions between the one inch marks with a 1/4" degree of accuracy.

It is also handy to have another scale or ruler running along the front edge of the board, which is used to quickly measure strips that need to be sized down across the short direction once cut in the long direction.

This cutting board will work for all the kraft, chipboard and poster board you need to cut for making single break shells up to 8". The longer strips required for multi-breaks will often exceed the built-in scale on the board and you will have to hold out a metal yard stick butted up against the hold-down bar when pulling large sheets out to size. If you plan to cut a lot of large pieces for this purpose, you could consider installing the cutting board at the end of a long table with a graduated scale along it's edge similar to those found in a fabric shop. However, this arrangement will sacrifice the comfortable position of cutting while standing directly in front of the cutter.

It also helps to install rubber feet or sit the cutting block on top of anti-slip rubber cabinet liner material if you will be using it on a Formica table top or similar slippery surfaces. You could just bolt it down, but it is worth while to keep the cutter portable if there is even a remote chance you need to take it with you for a group construction project somewhere. Once you use this tool, you will find it frustrating to return to the old fold and cut method or, even worse, drawing lines on paper and cutting with scissors!

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Rolling Precision Round Stars...

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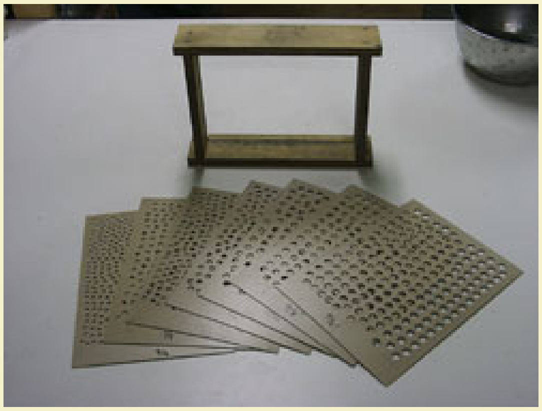

Figure 7: Screen box with interchangable screens.

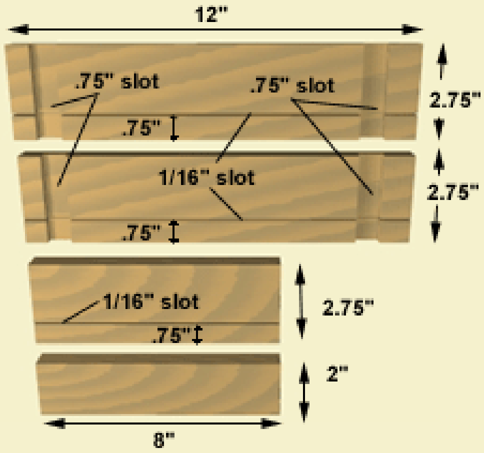

Figure 8: Screen box frame dimensions.

Screening Round Stars:
The key to any good round shell is good round stars, and good round stars can only result from good sizing technique. Poor size consistency will result in sloppy effect transitions. Anyone wishing to make a color changing ball shell that blinks from one color to the next with unified precision needs to start with a good set of sizing screens to achieve this.

Some people think I'm obsessive, but I actually screen my stars up to 3/8" dia. with 1/32" accuracy. While this may seem like a high tolerance, 1/32" of a 1/4" star is actually only a 12% tolerance. Screening to 1/16" simply results in too much size variance for precision color changing timing, but will work fine for simple solid color stars.

With a 1/32" tolerance, you find yourself needing more screen sizes of course. The screens listed in the process diagram on the next page call for 3/16", 1/4", 9/32", 3/8" and 13/32" screens. Since ordering such wide variety of odd sized perforated metal to use for screening would get expensive, I prefer to make my own. Because you are not going to be processing 100s of pounds of stars each day, a small 12" screen box will work just fine. Smaller screens are easier to handle and will be easier to build screens for.

Figure 7 shows a screen box with interchangeable screens that are made from sheets of Formica with holes drilled in them. The Formica drills easily without gumming up the bit and the thin sheets allow stars to drop through easily without getting stuck in the holes. Drilling the holes is of course a rather tedious task, but a drill press will help to make it easier. You only have to make the screens once and they will last a long time, so just think of it as a meditative exercise!

Figure 8 shows the dimensions for the screen box, which will require a table saw or radial arm saw to make due to the slotted groove and dado joints. Note the non slotted piece that leaves an opening for the sheets to slide into at one end.

Of course you can simply find some cheap plastic bins and drill a bunch of holes in the bottom as well. Some hobbyists drill holes in the bottoms of 5 gallon buckets and stack them up in order of largest to smallest, then dump their stars in the top and shake this "screen tower" such that the stars settle out at the various levels.

Figure 9 shows a screening operation in progress. You really need three bins: one to hold the initial star batch, one to catch the stars that fall through the screen and one to store the stars that stay on the screen. A scoop made by cutting the bottom off a 1/2 gallon juice or milk jug makes an excellent star scoop. However, scoops such as this will sheer pieces of damp stars off, so only use it on dry stars.

The basic process is to roll a whole lot of 3/16" cores, screen out the sub 3/16" for use as micro stars and then roll the rest on to 1/4" stars. I prefer to dry the stars at 1/8" increments, which allows them to dry in only one day. Trying to roll too much comp onto stars in one sitting not only makes them take longer to dry, it requires you to screen them more frequently while still wet, which can be a source of chipping and other damage.

Figure 10 shows how a good batch of accurately sized stars will align themselves into a very snug and symmetrical pattern when laid flat. You should see hexagon outlines as each star aligns perfectly with those around it. You then know you have achieved the Zen of star rolling!

More...

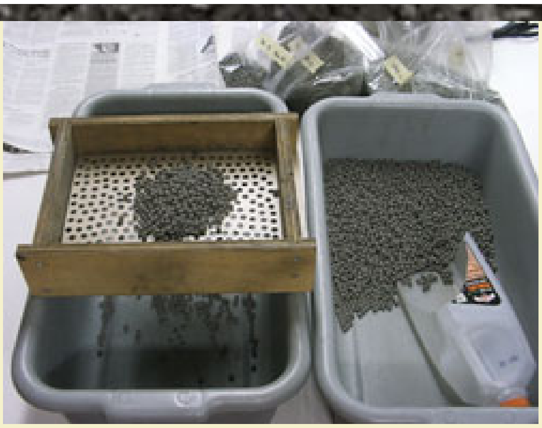

Figure 9: Screening setup.

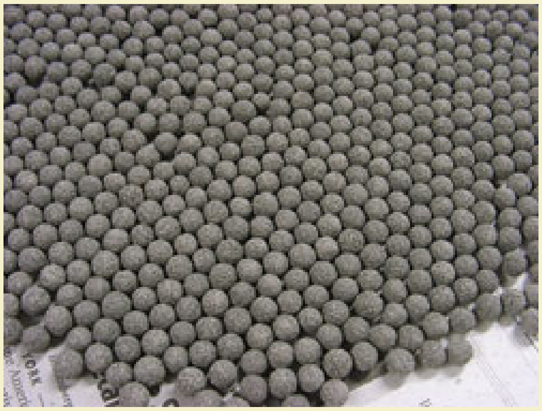

Figure 10: Well sized stars will align into a tight fitting pattern.

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Volume 5, Issue 2

Tool Tip...

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Shell Builder's Workbench

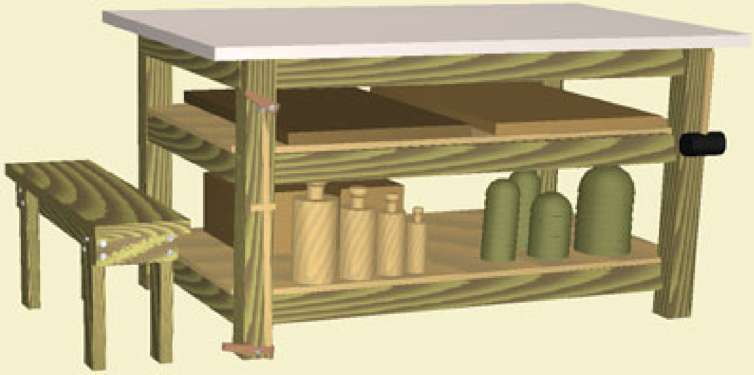


Table:

- (4) 35" long 4x4s
- (6) 60" long 2x4s
- (6) 36" long 2x4s
- (2) 72" x 42" x 3/4" thick particle board
- (1) 72" x 42" Formica laminate
- (2) 63" x 40" 1/2" plywood
- (24) 3" long 1/4" lag bolts w/washers
- (16) 1-1/2" long #8 wood screws
- (1) quart contact cement

Optional Bench:

- (4) 16" long 2x4s
- (2) 9-1/2" long 2x4s
- (2) 32" long 2x4s
- (1) 40" long 2x12
- (16) 3" long 1/4" lag bolts w/washers
- (4) 2" long 1/4" lag bolts w/washers

Introduction:

Every pyro workshop where shells are to be built should include a large, central work table. The size of this table will dictate the size of the shells that can be built in the shop, so starting with the biggest table you can comfortably fit in your shop will ensure you have the capacity to handle more ambitious projects as you develop your shell building skills.

A shell building table needs to have two key characteristics: 1) a solid frame that absorbs pounding from above and does not sway from strong pulling forces such as when spiking shells and 2) a tough surface with a smooth texture that can be easily cleaned, is waterproof, resistant to acids and solvents and is resistant to scratches and long term wear.

The workbench shown here has both these features plus a paper shelf and a built in hands-free spiking horse located conveniently along one of the sturdy table legs. The paper shelf is a nice thing to have if you work with sheets of paper instead of rolls, since it allows you to store the sheets flat while still being able to conveniently access them while you work. This table will accommodate two stacks of 36" x 24" paper, a standard size for shell building. Typically one stack would be your heavy 60-70lb kraft for case rolling while the other stack would be your lighter weight 30-40lb kraft for nosings, outer wrappers, match pipes etc.

An optional bench is included as it is useful as a seat when using the foot operated spiking horse. A long bench such as this allows you to straddle it long-ways so that you have a surface in front of you to rest shells on when spiking large shells. The bench also works well for Maltese spiking, where you sit on the strands of spiking twine as a means of controlled tension. When not in use, the bench fits nicely at the end of the table and provides a handy secondary table top for piling things on as you work, such as paste buckets, hand washing buckets, boxes of end disks and other supplies you need to access as you work.

Note that the dimensions for the table given here are about as small as you would ever want to make. You can change the dimensions to get a larger table up to a maximum of 4x8 feet in size without increasing the costs of building the table. If you have space for a larger table, then it is recommended you scale this project up because larger tables allow larger projects, multiple smaller projects or multiple people working from the same table.

Building the Table:

The first step to building the table frame is to cut the four table legs made from 4x4 posts so that they are 35" long. These will likely be made from treated outdoor lumber, since it is hard to find untreated pine in this size. The treated wood tends to be heavier and stronger anyway, so they make a good table frame. Do not try to skimp on the table legs by using smaller sized lumber, the 4x4 posts are essential in providing a sturdy pounding area when pleating canister shells or even pumping comets using a mallet.

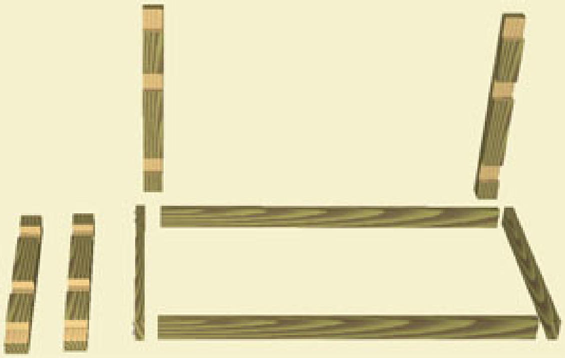


Figure 1: Each of three shelf frames are assembled on a level floor.

Once the table legs are cut, you will need to make three notches in each leg, which is where the frame will intersect. The bottom notch should start 5" from the bottom end of the post, while the top notch goes right at the top end of the post. The notch for the paper shelf should start about a foot down from the top of the post. All three notches are 3-1/2" long and 1-1/2" deep, such that a 2x4 will fit snugly into them and lay flush with the surface of the post. If the 3-1/2" dimension is exceeded by much then the table may be prone to wobbling, so only cut just enough to hold the 2x4 frame members.

Using notched joints is essential in building a table which does not rock when pushed or pulled on. The notches are easier to make than you might think, and are done by making several cuts that are 1-1/2" deep and about 1/2" apart for the entire 3-1/2" length of the notch. This means you will have to make about 10 cuts per notched out area, so a skill saw, table saw or radial arm saw is almost a must-have tool. Once the parallel cuts are all made, the thin wafers of wood are knocked out using a hammer and chisel to get the desired notch. You will have to clean up the bottom of the notched area a bit using the chisel to smooth out the jagged break-off points.

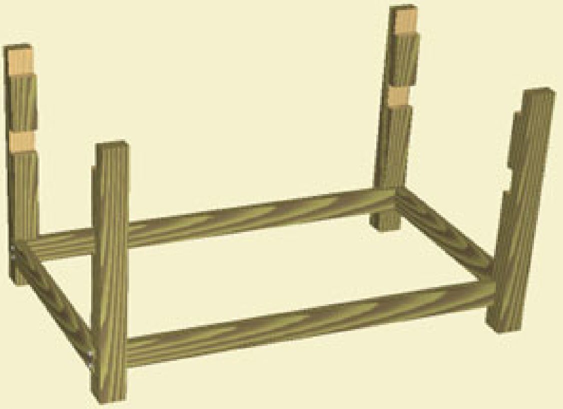


Figure 2: Shelf frames are fastened into nothced 4x4 corner posts using one lag screw on each joint.

Next you will assemble each of the three shelf frames on a level floor surface. Use two of the 3" long 1/4" lag screws at each end of the short pieces to hold the frame together, as seen in Figure 1.

You will want to assemble this table at its desired location, because it will be very heavy and difficult to move around. The table is assembled starting with the bottom frame, which should lock into the notched posts as seen in Figure 2. Only a single 3" long 1/4" lag screw is required at each joint, fastened from inside the frame, through the long frame members and into the post.

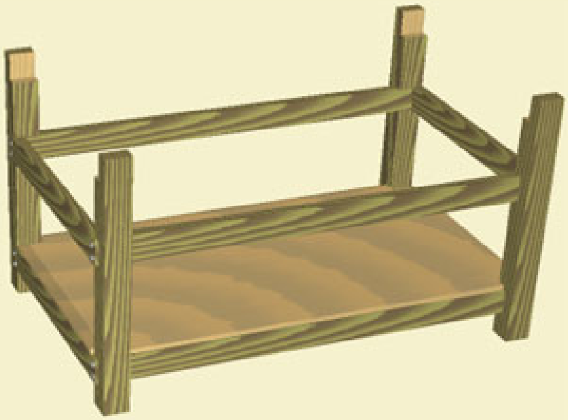
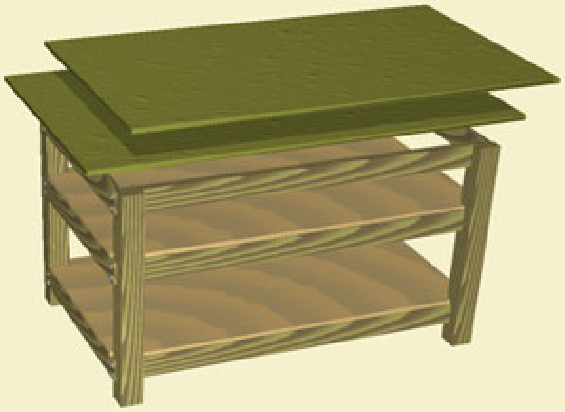


Figure 3: Each plywood shelf is put in place before adding the next frame.

The plywood shelf for each frame needs to be put in place before inserting the next frame, otherwise you will not be able to get it into place. Note that each plywood shelf will need to have 3-1/2" x 1-1/2" notches cut out of each corner so that it will fit around the posts. Each shelf should be fastened to the frame using wood screws or nails prior to installing the next frame above it, otherwise it is harder to work between the frames.

The paper shelf is constructed just like the bottom shelf, as is the final top shelf. The top shelf does not get a plywood floor though, rather it is fitted with the final table top. As seen in Figure 4.



The table top needs to be at least 1-1/2" thick to provide a sturdy surface. Particleboard is the material of choice for table tops because it is not prone to warping like plywood, plus its high density is better at absorbing vibration than an equal thickness of plywood or wood boards. Particle board can ocassionaly be found in 1-1/2" thicknesses, but it is easier to just stack two standard 3/4" boards on top of each other to get the desired thickness.

The tabletop sheets are first cut to size, then the first one is screwed down onto the underlying support frame. The second sheet is then screwed down onto the first sheet. Be sure to counter sink the screws in both sheets so that the screw heads do not rise above the table surface. A #8 wood screw that is 1-1/4" long works good for this task.

To finish off the table, you will need to laminate the top surface with Formica. Formica has the best resistance to wear, acid and solvents, and is also

Figure 4: Table top is made from two sheets of 3/4" particle board screwed together and laminated with Formica.

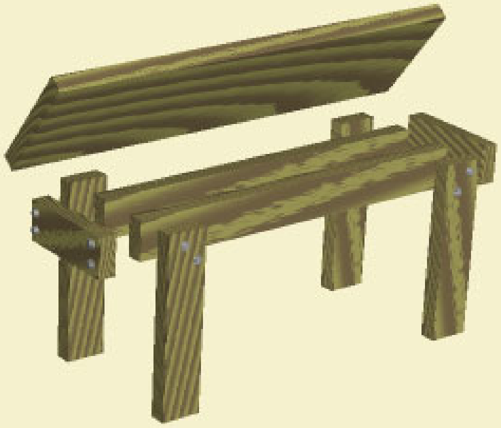


Figure 5: Assembly of optional utility bench.

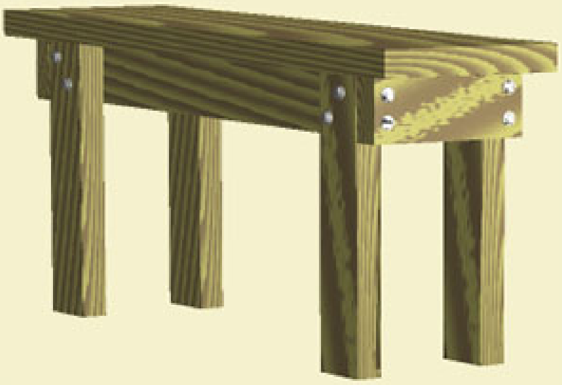


Figure 6: Assembled bench showing placement of fasteners.

relatively cheap. You will want to get a solid color, preferably a light color like white so that you can tell when it needs cleaning. Formica seems to have two common surface textures: glossy smooth and matte. The glossy type works good for removing dried paste, but it scratches more easily than the matte type. I prefer the matte finish because it is tougher and you can run a chisel over it without scratching it.

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Shell Builder's Workbench...

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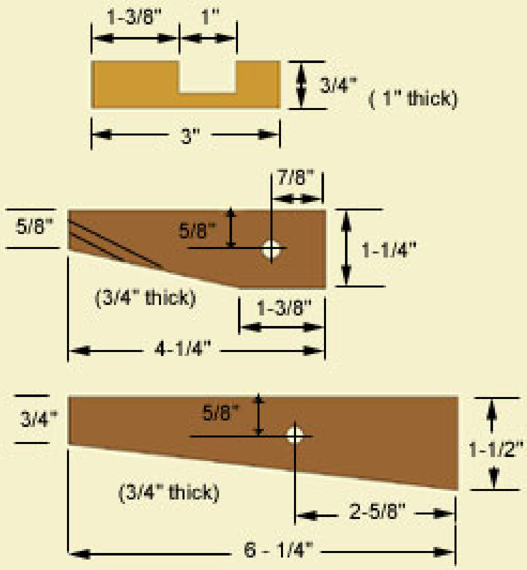

Figure 7: Dimensions for spiking fixture parts.

If you have never done laminate work, don't worry because it isn't that hard. First cut your Formica sheet so that it is slightly larger than the table top. Formica can be cut by scoring the back with a razor knife and then bending the sheet until it snaps in half on the line.

Next coat both the table top and the back of the Formica with contact cement. There are a few different types of contact cement on the market, but the original nasty smelling stuff seems to work the best. The fumes are so strong from this cement that you will probably need to wear a good respirator mask. It's pretty difficult cleaning contact cement out of a paint brush, so just use an old brush or a disposable brush and toss it when you are done.

The contact cement is allowed to dry for about 30 minutes or until it is dry to the touch. Now for the tricky part-- you have to position the sheet over the table exactly where you want it without letting it touch the table. You really need another person to help you with this step, because as soon as the sheet contacts the table it is going to stick so you don't want it to get stuck in the wrong position. After you make sure that the Formica sheet is positioned so that it will overhang all edges of the table, drop it down in place. Use a rubber mallet to pound it flat all over the surface so that it comes in full contact at all points.

The last step is to trim the overhanging Formica around the edge. If you have a router and a laminate trimmer bit, this task takes only a few minutes. If not, well... you might want to think about borrowing, renting or picking up a used router for this task. Otherwise you could try hacking it with a thin kerf Japanese saw and sanding down the jagged edge that results.

Foot Operated Spiking Fixture:
A nice addition to your workbench is the handy spiking jig shown in Figure 8. This spiking "horse" is unique in that it can be used both standing up in the traditional way and sitting down. When used standing up, the fixture is basically a sideways version of the spiking horse shown here. However, in smaller shops there may not be enough room to spool out 15 feet of twine for spiking in the traditional manner.

This side mounted spiker features a foot operated lever that actually allows you to spike a shell while sitting right in front of the device. This is ideal for space constrained shops, and may even be a preferred method of spiking once you get the hang of it.

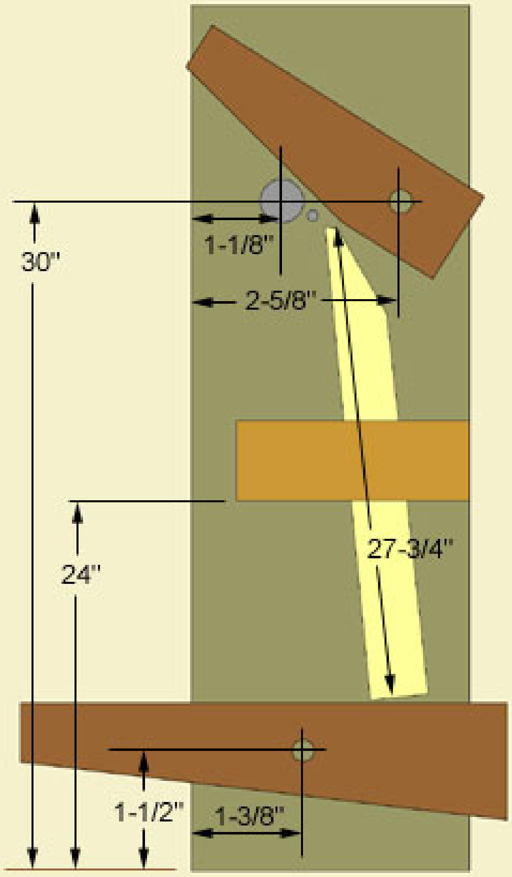

Figure 8: Placement of spiking fixture parts, located on the side of any 4x4 table leg.

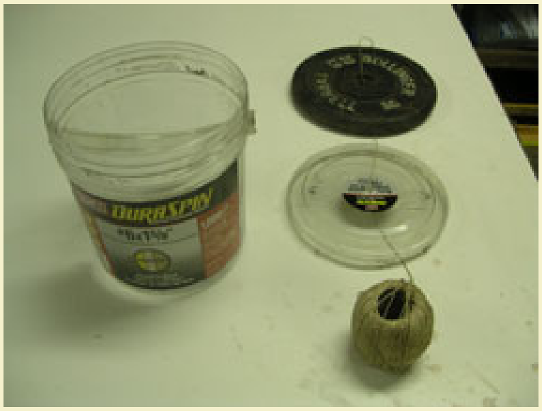

Figure 9: Using a bucket and 10lb dumbell weight as a string dispensing bin.

When used sitting down, the operator presses down on the foot lever each time he needs to spool out more string. The lever pushes a rod up that takes the clamping bar pressure off the string so that it can be pulled out. The operator then releases the foot petal at the same time he pulls on the twine to bring the lever back down to lock the string in place. Enough string can be pulled out to spike a couple of turns around the shell, then the process is repeated. It is awkward to coordinate at first, but can be quite fast once you get the hang of it!

To build the spiking attachment, fabricate the two levers shown in Figure 7 from some scraps of hard wood such as oak or maple. Soft wood like pine will not work due to the weak grain, which will split apart when pulling hard on the string. Note the small 1/8" diameter hole that must be drilled at an angle through the smaller lever. This is where your twine will pass through.

The 3" long guide block can be made from pine, since it is only used to keep the push rod in place. The push rod used here is square, but a round dowel rod could easily be used as well. If using a dowel rod, you could then just drill a hole through the guide block instead of cutting out a square channel.

Figure 8 shows how the pieces are mounted onto one of the workbench legs. The 1/4" bolts used as the pivot points are not tightened all the way so that the levers can freely move. A washer is placed on the back side of each lever as a spacer so they don't rub against the table leg. Note the small nail shown behind the aluminum pin in Figure 8. This nail keeps the push rod from binding the spiking twine against the aluminum pin when lifting the lever to spool out more twine.

A small eyelet is used under the 1/2" diameter aluminum pin in order to guide the incoming twine, which can be seen in Figure 11. The larger eyelet in Figure 11 is used for Maltese style spiking, as described here.

A simple fixture for holding the twine can be made using a bucket and a 10 lb dumbbell weight as seen in Figure 9. The nice thing about this simple string bin is that it will work for any kind of twine configuration, including balls, cones or cylinders. The twine just tumbles in the container as the string is pulled off, rather than requiring a your string to have core that fits over a dispenser.

To load the dispenser, the twine is first passed through a hole in the bucket lid, then through the hole in the dumbbell weight. The twine is then closed inside the bucket and the weight placed on top to keep the bucket from lifting or falling over as the twine is pulled. This setup is then placed under the spiking horse as seen in Figure 10. The twine is then passed through the eyelet, over the top of the aluminum pin, then looped around the pin and up into the hole of the clamp lever as seen in Figure 11.

As a finishing touch to your completed shell building workbench, segments of cloth measuring tape can be stapled to the edges of your table top for quickly measuring lengths of string, paper, blackmatch and other common items, as seen in Figure 12.

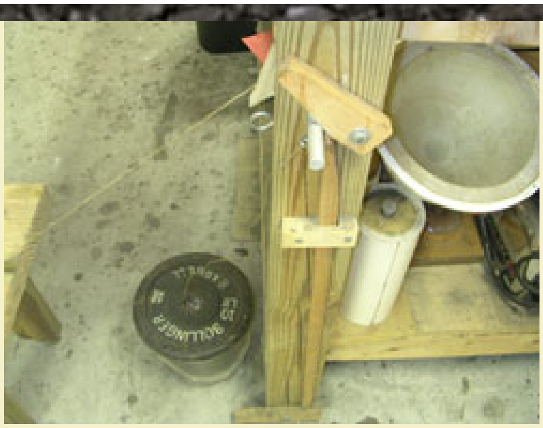

Figure 10: String dispenser placed on the floor under the spiking fixture.

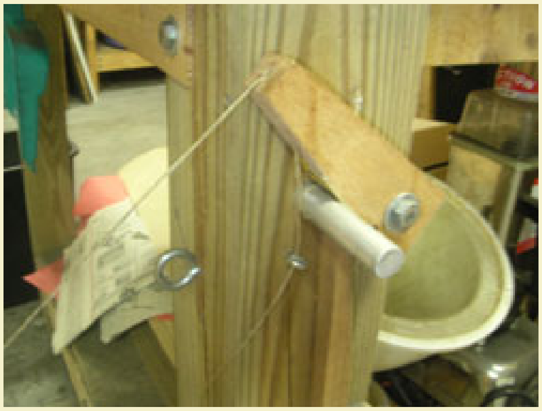

Figure 11: Closeup showing the spiking fixture strung and ready to use. Note the small eyelet to guide the string.

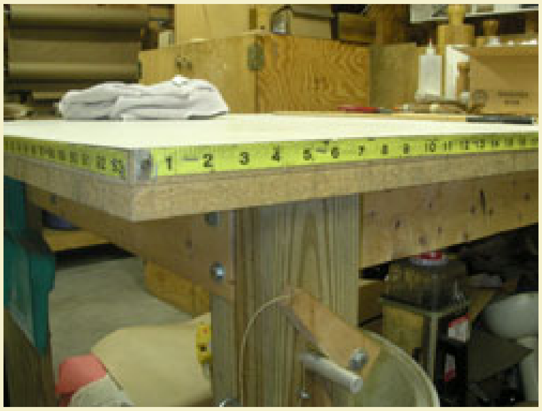

Figure 12: Measuring tape fastened to edges of table top for quick measurements.

Another feature not shown here but common to commercial shell building tables is shielded razor fixed to the table near the spiking area, such that string can be quickly cut by pulling it into a slot that leads to a razor blade. The narrow slot is large enough to pass a string into but not a finger, for obvious safety reasons.

With the permanent spiking horse, tape measures and cutting device, the number of tools that the operator has to have on hand and manipulate is minimized and efficiency is increased. The paper shelf and storage area helps keep the most commonly used items close at hand, thus optimizing your time spent in the shop!

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Tool Tip...

Page 1

Simple Spiking Horses You Can Build

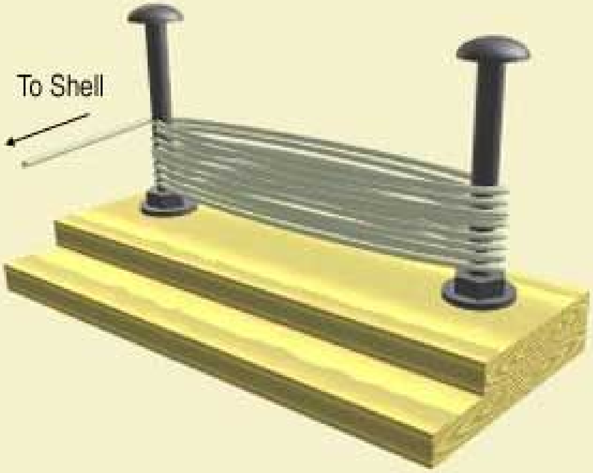

Figure 1: Two post spiking horse.

Any device that aids in wrapping twine around a canister shell is known as a spiking horse. This stringing process, called spiking, requires that strong twine be wrapped as tightly as possible around the shell in order to insure a good break. While this can be managed by holding down the shell with one hand and pulling the twine around it tightly while wearing a pair of gloves, this method is tedious and much more labor intensive than it has to be.

The spiking horse came into use in order to reduce the fatigue on the hands and arms of workers, as well as alleviate the irregular tension that results from hand spiking. The name itself implies an immovable structure with "legs," perhaps nothing more than two posts buried in the ground. These parallel posts are "loaded" by wrapping the proper amount of string between them, then unwound onto the shell as the worker keeps tension on the string using his body weight. This simple type of spiking horse can easily be implemented using any two well grounded posts. A table-top model can also be constructed using carriage bolts and wood as shown in Figure 1, then clamped or permanently bolted to a sturdy table.

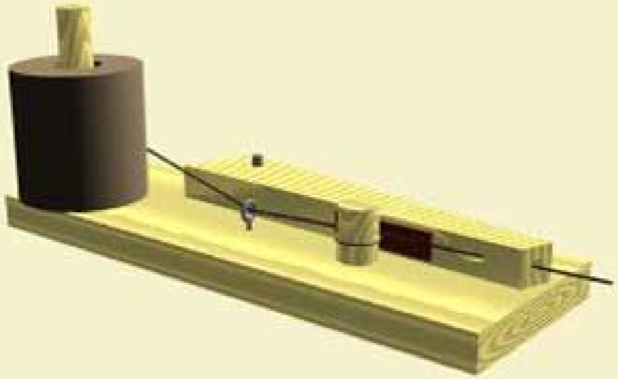

Figure 2: Arm type spiking horse.

The two-post type of spiking horse has two advantages: it is easy to improvise or build and it allows paste to be applied to the string before spiking. On the down side, this type of horse requires the worker to first wrap string around it before spiking the shell. If the correct amount of string is not loaded onto the horse, the builder could run out of twine before the spiking is completed or, in the case that too much twine was loaded, having to throw away leftovers (given the current prices of flax twine, one hates to waste any).

One solution to loading the correct amount of twine is to use the shell to be spiked to measure out the twine. The builder can quickly loop the twine around the shell the desired number of horizontal and vertical passes, then wind it from the shell onto the spiking horse. Of course, this creates yet a third wrapping process just to get the string to its final destination.

Another type of spiking horse, shown in Figure 2, has the advantage of using string directly off the spool. When the string is pulled straight out from the pivot arm, it freely rolls off the spool. When the direction of tension is brought around perpendicular to the lever arm, the arm binds the string against a stop post and prevents any further unspooling.

When using this type of horse, it is first firmly clamped to a heavy bench top using c-clamps or bar clamps. The worker begins by tying off the string to the time fuse, then pulling out about ten feet of slack. The worker then backs away from the horse perpendicular to the lever arm so that the arm binds the string against the stop post, preventing any further unspooling as tension is applied. Using his body weight to keep the tension, the builder rolls the shell up in the twine as tightly as possible. When the worker arrives back at the horse, another ten feet is pulled out and the process is repeated until the shell is fully spiked. See the article on spiking basics for more details of the spiking procedure itself.

More...

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Spiking Horses You Can Build...

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The shape and dimensions of the spiking horse are not critical, and many variations of this design can be found in use today. While usually made from metal, the wooden design depicted here works just as well and can be made from small scraps of wood for almost nothing.

When making your own version of this horse, begin by placing a roll of your spiking string onto the board you plan to use as the base plate. Mark its center and outer perimeter so that it does not interfere with the arm. If your twine comes in a ball instead of a roll, then it is best to place the ball in a coffee can on the floor beneath where the horse is clamped to the table, then feed the string up through a hole in the can lid and to the horse.

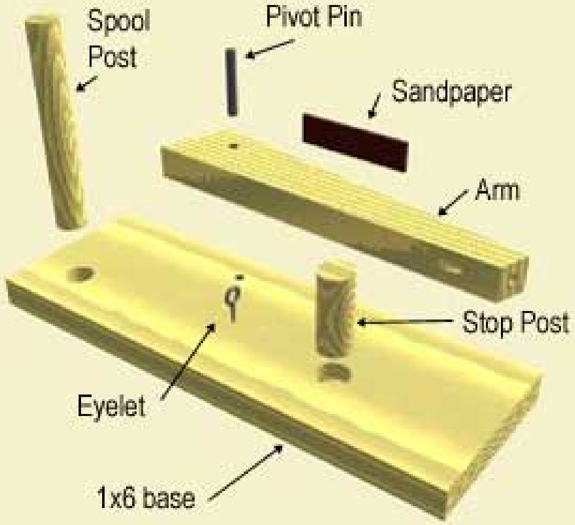

Figure 3: Spiking horse components.

Next, select a piece of wood to use as the lever arm and cut it to the general shape shown in Figure 3. It is advised to make the lever arm from oak, maple, or other hard wood since the forces exerted at the tip of the arm can be great enough to tear through soft woods like pine. The arm can be a straight rectangle or angled on one face as shown here, it really doesn't matter that much. The purpose of the angle is to shorten the length of the diagonal hole at the tip of the arm, making it easier to thread the string through it.

A pivot point is selected somewhere near the back of the arm, and either a small rod or wood screw is used as the pivot pin. A hole drilled through the pivot point of the arm is slightly larger than the pin to allow easy rotation. Finish the arm by drilling a small hole, not much larger than 3/16" diameter, through the tip of the arm such that it exists out the side facing the stop post. Making the hole to small will make it difficult to thread cotton twine through it, while making it too large will weaken the tip of the arm to where it might tear out during use.

With the arm in place, the next thing to do is select the position of the stop post. The longer the arm length is on the exit side of the stop post, the more clamping force there will be. Somewhere in the middle of the arm is good. Both the spool post and the stop post are secured by gluing them into holes drilled in the base plate.

Due to the tendancy of the string to ride up and down the stop post during use, an eyelet is placed near the post to guide the string to a position level with the midpoint of the arm. Finally, a small strip of sandpaper is glued or stapled to the part of the arm that comes into contact with the stop post. This helps create additional friction against the string and further reduce any chance of slippage during the high tension of spiking.

The spiking horse must be firmly mounted when in use. If a heavy workbench is not available for this purpose, it may be fastened sideways to the wall with the arm pointing upward between 30 to 45 degrees. When threading the string onto the horse, it goes through the eyelet, one turn around the stop post, then through the hole at the end of the arm.

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Tool Tip...

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Star Cutting Tools

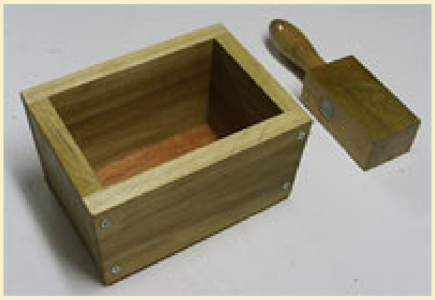
Figure 1: A loaf box with rammer.

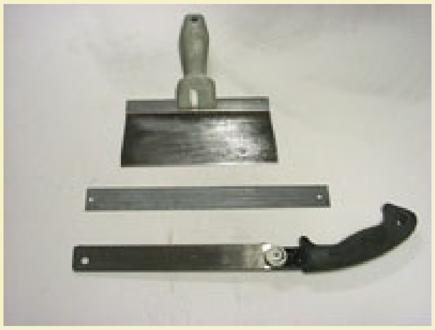
Figure 2: Various common tools that can be used for cutting stars.

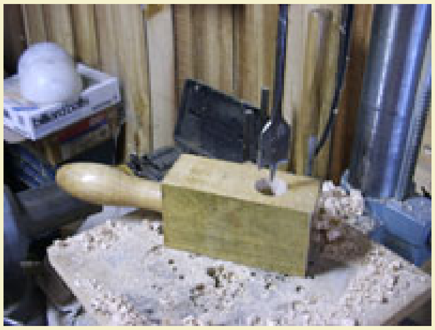
Figure 3: Making holes in rammer to fill with lead.

Introduction:
Cut stars are one of the fastest methods of producing stars, and several methods of making them exist. The tools shown here are used for the commercial method described here, also called the loaf method.

There are three tools required for making stars using the loaf method (so named because a thick loaf of comp is produced in the process): a loaf box, a packing rammer and a thin blade for doing the actual cutting.

The Cutting Tool:
A variety of objects can be used for the cutting tool, such as drywall blades, thin knives and any thin piece of metal that is not overly flexible. You do not need to make your own knife, although some builders do make some pretty nice star cutting knives using the thin metal from old hand saw blades. In fact, a thin kerf Japanese type hand saw with the teeth ground down makes an ideal star cutting knife. Figure 2 shows some examples of star cutting knives you can use.

The Ramming Tool:
The ramming block used to compact the comp can be any square block of wood or metal with a handle on it. The one pictured in Figure 1 is made from rock maple, with a handle turned down on a lathe. A piece of 2x4 with a dowel rod glued into one end for the handle can work as well, or even notching out a handle with a band saw or saber saw, then whittling the corners down with a knife.

However you go about making your ramming block, it needs to be pretty heavy to assist in the ramming process. If you make one out of a block of aluminum, then it will be heavy enough as-is. Wood rammers tend to be too light and result in more work required to tamp down the composition into the loaf box. An easy way to make wood rammers heavier is to drill large cavities in the sides and then fill them with lead. Figure 3 shows a 1" hole being bored into the side of a rammer on the drill press. Care must be taken that the tip of the spade bit does not break through the other side of the rammer, otherwise the lead will leak out the hole when poured.

Figure 4 shows how two separate lead cavities are arranged in opposing directions in order to balance the weight of the rammer.

Lead can be melted in a small stove pan using a Coleman propane burner that screws onto a propane can. This arrangement should be surrounded by bricks or cinder blocks such that there is no way the pan can be knocked off the burner. Lead tire weights, flashing or other scraps are placed into the pan and melted, then a metal ladle is used to pour it into the cavities in the

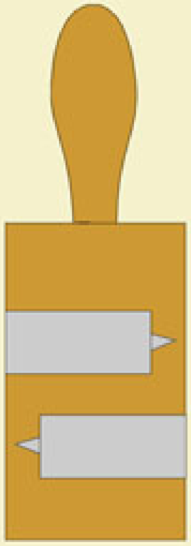

Figure 4: Two cavities drilled in opposing directions for balance.

rammer. Extreme care should be taken when working with molten lead! A respirator should be worn to avoid breathing lead fumes, and protective goggles, long pants, long shirt sleeves and gloves should be worn. Molten lead can sometimes bubble due to air pockets in the mold or mixing with water, so be prepared!

The lead should be poured in two increments, allowing the first one to cool and shrink before pouring the second. The second pour should fill the hole completely to almost overflowing, such that the rounded surface area extends just barely beyond the edge of the hole.

It helps to cool your lead down with water after it solidifies so that the hot lead will not start to burn the wood. Once the lead is cool, flatten the ends down with a hammer so that the lead spreads flush with the sides of the rammer. This helps lock the lead in place as well as remove any cavities for powder to get stuck in.

If you do not wish to deal with molten lead, you can also drill your holes all the way through and press-fit steel rods into the rammer. This will not add as much weight as lead will, but it is still better than nothing. The rods must fit tightly so that they do not slip out over time.

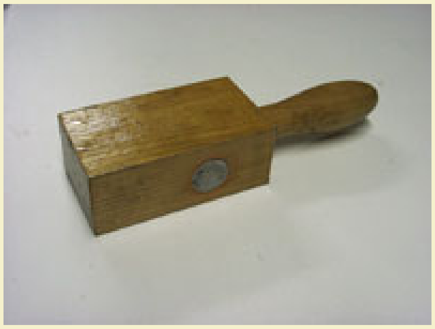

Figure 5: Lead is poured into cavities and hammered flush with sides.

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Star Cutting Tools...

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Making A Loaf Box:

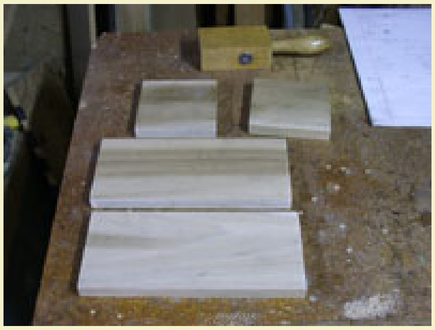

Figure 5: Side pieces prior to cutting side angles.

The next thing you will need is a special box with slightly tapered walls to form the loaf in. It is important that the walls have a slight taper so that when the box is inverted the loaf will fall out. The taper should be minimized however, since it is desirable to have the loaf as close to being square as possible.

While it is possible to use the aluminum bread pans available in most kitchen supply stores for making your star comp loafs, bread pans tend to have too much of a taper, have patterns on the bottom that imprint into the loaf and are not as deep as an ideal loaf box for cutting stars. Making your own box allows control of the exact shape and size of the loaf so that you can match it with the batch sizes you commonly work with. The dimensions of the loaf box shown here will hold a maximum of 2 Kg (4.5 lbs) of comp per loaf. If you do not have the tools or skill to fabricate the box shown here, then the aluminum bread pan makes a useable substitute.

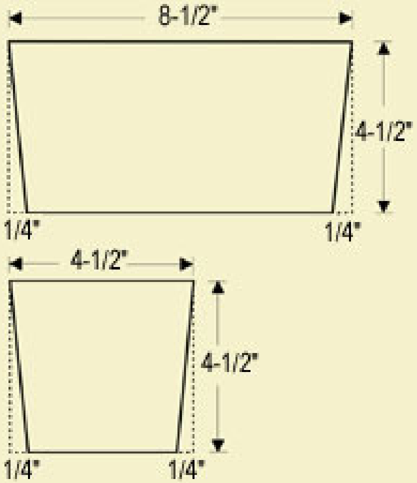

Figure 6: Wood sides with taper trimmed 1/4" from each end.

The loaf box will be about 4" tall with an inside cavity of 4-1/2" x 7." Start by ripping a 28" long board to a width of 4-1/2" on your saw. From this board, cut two pieces that are 4-1/2" long and two more pieces that are 8-1/2" long. The extra 1/2" on the height of the walls is to compensate for material that will be lost when the top and bottom of the assembled box are trimmed. Trim each side so that there is a taper that moves in 1/4" from the bottom on both sides of all pieces. This gives you two sets of pieces that should look like Figure 5.

Once the four sides are prepared, glue is applied to the edges of the two shorter pieces and the box is held together with bar clamps while it dries, as seen in Figure 7. Two 1-1/4" #6 wood screws are then used to reinforce the butt joints at each end (8 screws altogether). These should be counter sunk so the screw heads are flush with the wood.

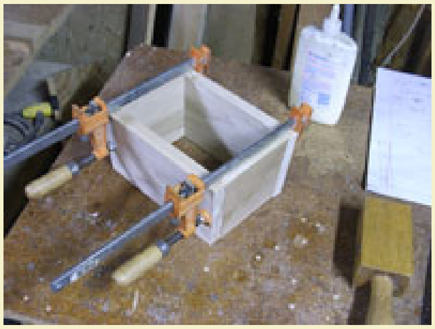

Figure 7: Using bar clamps to glue the pieces together before strengthening with screws.

Now that your box is assembled, you will notice that the angled sides has resulted in the top and bottom edges not being in a flat plane. There are a number of ways to level off both sides of the box. My favorite way is to use a radial arm saw with the motor locked in a horizontal position as seen in Figure 8. The box is simply slid against the fence (keeping your hands below the cutting plane) for all four sides. The blade is then lowered slightly and the process repeated for the other side. All four sides will then be trimmed to the same height and horizontally level.

Other ways to level the box include using a hand plane or belt sander. One easy way would be to hold the box down against a wide horizontal belt sander until it was flattened. While the top isn't as important, you will need to level the bottom to that bottom of the box will fit flush.

Lastly, you need to measure the bottom of your box and cut a piece of thin plywood to fit over it. I used 1/4" Luan underlament sold in most home

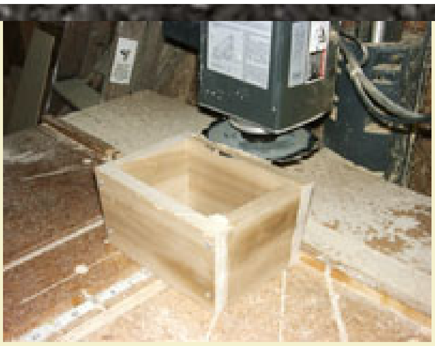

Figure 8: Using a radial arm saw in the horizontal plane to trim top and bottom edges of the box.

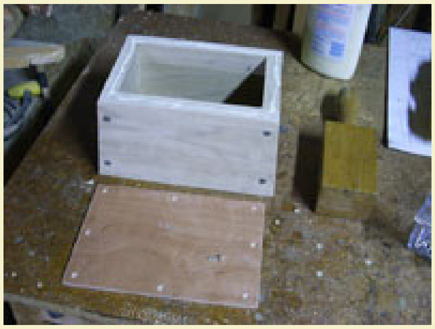

Figure 9: Thin luan plywood is glued flush to the bottom and held by small screws.

improvement stores. The bottom will be held on by both glue and screws, so you will need to counter sink the screw holes so that the screws don't stick out and scratch up your table when ramming comp into the box. Figure 9 shows the bottom edges glued and the bottom pre-drilled with the counter sinks prior to attaching the bottom.

Once your box is complete, you will need to water proof it so that you can hose it off after each use. Spray-on acrylics, polycrylics or polyurethanes like Krylon or Minwax work good for this. Using just an oil stain will cause problems during use, since masking tape will need to adhere to the sides of the box and oil stains do not allow the tape to stick.

Well, I have a feeling everyone just rushed to the store to buy a bread pan, but if there are any wood workers out there then this would probably be a quick-n-easy project for you.

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Design Notes...

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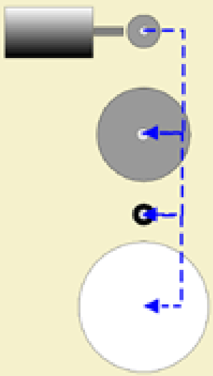
Star Roller Design

Introduction:
Star rollers are a simple yet essential tool in every pyrotechnicians workshop. Rolling stars by hand in a large bowl is so tedious and slow that I find little value in the experience even for the beginner. I was personally driven away from making round stars by the experience of rolling them by hand early in my pyro endeavors, and it wasn't until I built a machine to roll stars years later that I realized what I had been missing out on. Rolling stars using a simple machine to rotate a drum full of stars is without question the most efficient way to make stars of any kind. There is good reason why the round star is preferred by manufacturers who are engaged in large scale production, such as the Chinese, Japanese and even Maltese shell builders. It is simply the most flexible and efficient star to produce compared with cut, pumped or any other method of star production.

Drive Train Calculator:

Enter values for five of the six parameters below in order to solve for the missing parameter. You can use this to calculate the required motor speed by entering all drive train diameters plus the desired bucket RPM.



Motor Speed:
RPM
Pulley #1 Dia.:
Pulley #2 Dia.:
Drive Roller Dia.
Bucket Outside Dia.:
Bucket Speed:
RPM

Calculate

Speed Selection:
One of the most common questions regarding star roller design is "what speed should the drum rotate?" Well, there is no magic number of RPMs that can be applied to all star rollers. This is because speed is dependent on the diameter of the rolling drum, as well as on the personal preference of the person doing the rolling. The faster you roll the stars, the faster they will pick up composition (up to a certain point anyway). But if you rotate too fast, you start having problems with stars getting thrown from the bucket. Higher speeds can also cause the star pile to slide as one big pile with no tumbling action occurring.

For a 14" diameter drum, 30 RPM works good for the range of stars beginning with cores up to about 1/2" diameter. For the 24" diameter tire roller shown on the next page, I also rotate at about this same speed. The rolling action in the 24" diameter tire moving at 30 RPM is much more aggressive than the 14" diameter drum. Since there is no concern for stars getting thrown out of my tire roller and the traction inside the tire prevents the sliding star pile problem, I can get away with a higher speed than a conventional design would allow. Note that even though both the 14" roller and the 24" roller are rotating at 30 RPMs, the 24" roller is "faster" because there is more drum wall passing under the stars each minute than there is with the 14" drum. To keep the rolling action the same for larger and smaller drums, you would have to slow down the speed as the drum diameter increases or speed up the RPMs as the diameter decreases.

You can actually figure out the desired speed for your own rolling bucket using the 30 RPM number for a 14" diameter drum given above. You have to convert this spec into a number that corresponds to the linear amount of bucket wall passing under your stars per minute, which would be 1320 inches in this case (PI x 14 x 30rpm). You can use this number to solve for the RPM of any size bucket given its diameter using the following formula: RPM = 1320/(3.14 x Dia). Keep in mind that this speed is a little on the slow side but will work for a larger range of star sizes than if you went with a higher speed.

Since most star roller designs employ a motor with a pulley on the drive shaft linked to a second pulley on another drive shaft that drives the actual rolling bucket, the drive train calculator shown above can be used to determine the size of any one component after typing in all other values including the desired RPM of your rolling bucket. The Passfire tire star roller uses this exact same drive train as well, so replacing the word "bucket" with "tire" will allow you to calculate the drive train for a tire based roller. If your star roller design has fewer pulleys, you can effectively remove pulleys from the calculator by setting two connected components to the same value. For example, if you had a 2" pulley driving a 12" pulley that was directly connected to the rolling bucket as shown in Figure 2, you would enter 2 for "Pulley #1 Dia", then 12 for "Pulley #2 Dia" and also 12 for "Drive Roller Dia" as well as "Bucket Outside Dia."

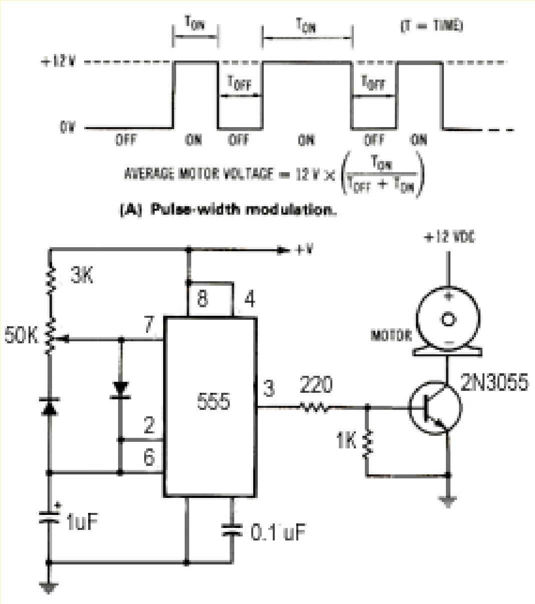


Figure 1: A simple PWM DC motor speed control circuit.

Speed Control:
The use of DC motors allows easier speed control circuitry compared with AC motors. Figure 2 shows a DC speed control circuit based on pulse width modulation (PWM), which can control the speed of a motor without losing torque at lower speeds. Trying to control motor speed by lowering the voltage applied to a DC motor will result in an undesirable loss in output torque as the speed is lowered. Since lower speeds are usually only needed when rolling large stars or large batches, this loss in torque occurs at a time when high torque is needed most!

The circuit in Figure 2 is based on a 555 timer chip, which used to be sold in any Radio Shack store in the form of an 8 pin DIP chip. The 2N3055 power transistor needs to be a TO-3 package mounted to a heat sink if you plan to build this.

The hazard with using DC motors in the presence of any pyrotechnic materials are the sparks generated by the motor brushes. An enclosed "explosion proof" type motor must be used for this application, which is a sealed type of motor where flammable materials or vapors can not be ignited by the brush sparks.

While DC motors allow easier speed control, they still require DC power supplies in addition to the speed control circuitry and are thus circuit intensive compared with AC motors, which can simply be plugged into a wall outlet. The simpler operation of AC motors, combined with the higher torque and brushless operation they feature, make them my personal preference for driving star rollers or any other kind of pyro machine. While dialed in speed control is a nice feature, it is not an absolute necessity. You will generally do most of your rolling at one speed, from cores up to about 1/2" size stars, then have a second slower speed for making larger stars. I find that using two different size pulleys on the drive shaft is all the speed control I need. The nice thing about pulleys is that they are simple, torque actually goes up at lower speeds and there are no electronic parts to assemble and maintain.

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Star Roller Design...

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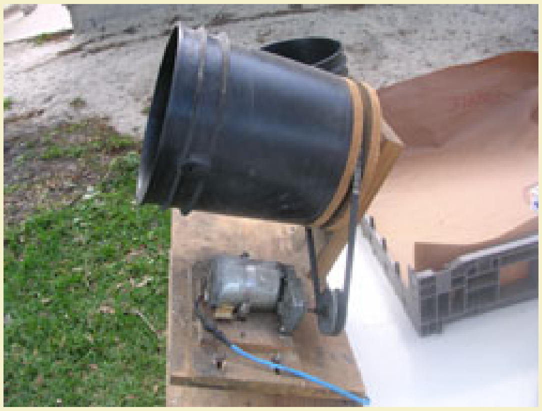

Figure 2: A simple 5 gallon bucket roller.

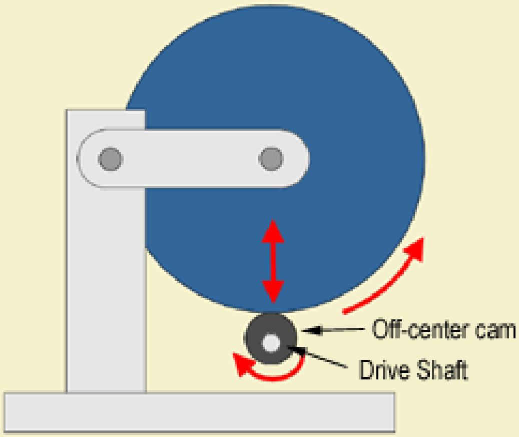

Figure 3: Off-center cam drive method of drum agitation.

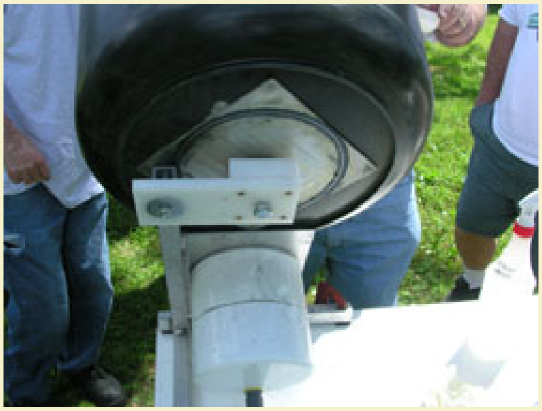

Figure 4: The mechanics of a Hobby

Machine Design:

Figure 2 shows a typical home-brew roller that uses a 5 gallon bucket as the rolling drum. Note the clever use of an improvised "pulley" made from circular wooden disks behind the bucket. This allowed the designer to control his speed reduction without the need to locate what would otherwise be an uncommonly large pulley wheel. A DC gear motor can be seen attached to a sliding plate that allows belt tension to be adjusted.

Rolling buckets invariably must be fastened to a spinning back plate or drive shaft. This usually results in the fasteners sticking out on the inside of the bucket, which presents problems when rolling stars. The bucket bottom must be flat and free of protruding fasteners, otherwise the fragile stars will rub against them and become damaged. Many rollers, including the one shown in Figure 2, get around this problem by doing the actual rolling in a second bucket that is inserted into the first bucket. This double bucket method also makes it easier to remove and transport the stars when rolling is completed, since you can simply pull the bucket full of stars out and put in a new bucket. Cleaning the buckets between rolling sessions is also easier with this design. This works quite well when the rolling drum is a beveled type bucket that is actually designed to fit inside other buckets for stacking and storage. Many flower pots and plastic buckets allow this technique to be used, while most cooking pots have straight sides and will not work this way.

Another feature commonly used in many star roller designs, including the Hobby Fireworks star roller, is the use of an off-center drive shaft to drive the rolling bucket. The bucket must be mounted on a hinged arm, as seen in Figure 3, so that it is free to move up and down as it sits on the drive shaft. The purpose of this design is to create a rapid shaking motion in the bucket, which serves to bounce the stars as they are being rolled. This helps break up clumps of stars in the early stages of rolling where stars tend to get stuck to each other due to their small size. Figure 4 shows how the Hobby Fireworks roller has cleanly implemented this design. Note the use of the PVC housing on the motor as a way to create an explosion proof motor from a cheaper standard motor.

As your thirst for round stars increases, your desire to roll larger batches increases as well. This is because it takes the same amount of time to roll a given batch of stars regardless of if it is a two pound batch or a fifteen pound batch. In fact, it is actually easier to roll larger batches than small batches. For large scale production of round stars, a converted cement mixer has been a tried and true method. The mixing fins must first be removed from the drum, and

Fireworks star roller.

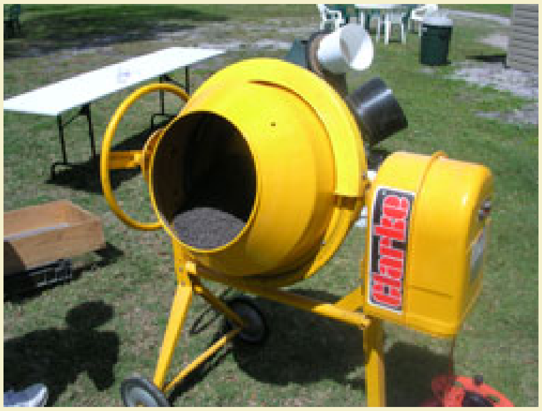

Figure 5: Cement mixers are popular high-volume rollers.

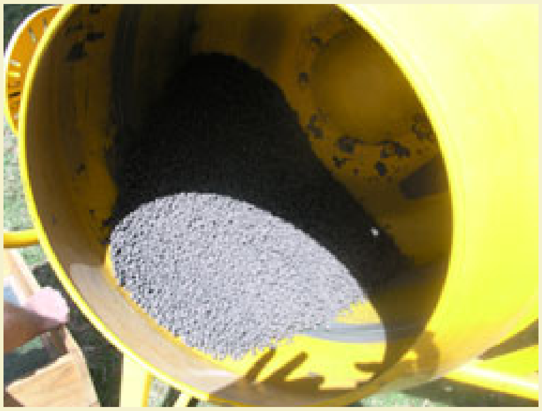

Figure 6: Closeup of a typical cement mixer star batch size.

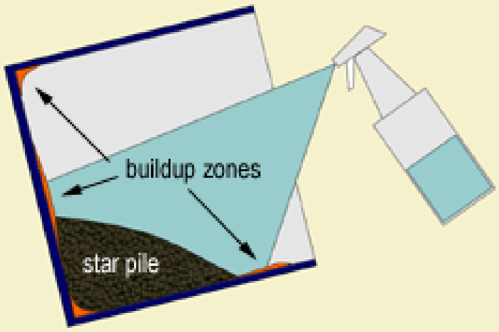

Figure 7: Common areas where composition collects in a drum type roller.

the resulting holes filled in. The mixing drum shown in figure 5 also has a seam inside the drum that must be covered with a strip of duct tape to keep powder from caking in the groove. Figure 6 shows a batch of 1/4" stars in production. Note the bolts visible at the back of the roller, which could cause problems when rolling larger stars or large batches of small stars. Be sure to select a mixer with minimal internal hardware or other crevices that will trap powder when going this route.

Conventional Roller Problems:
One of the biggest hassles with rolling stars using the type of setup shown in Figure 7 is the composition that sticks to the drum walls. This is less of a problem when using smooth metal drums, but is a big pain with many types of plastic drums. If the back of the drum meets the sides at a sharp angle, then comp will compact in this corner and slowly build up as you roll the stars. The Hobby Fireworks roller uses the cut-off bottom of a plastic 40 gallon drum, which has a nice rounded transition from side to bottom to eliminate this buildup zone.

Another cause of comp buildup occurs when the mister overshoots the star pile and wets the back and front edge of the rolling bucket. Stars do not contact the back of the drum, so the wet spots will collect loose powder and continue to build up until you scrape it off. Comp that builds up on the sides of the drum can be picked up by the stars if the buildup is sprayed directly and allowed to roll for a while. However, this technique doesn't always work and wastes time that you could otherwise spend adding more comp to the stars.

Once comp starts to build up in your roller, it will continue to grow and rob composition from your stars. If the stars can't pick it up, then you eventually have to scrape it out manually. Sometimes considerable amounts of composition will be wasted this way, or force you to pump it into comets in order to utilize your expensive materials!

Another problem that occurs in star rolling is the tendency for the small stars to work their way to the bottom of the roller while the larger stars make their way to the top. This results in the larger stars being first to receive new composition, while the smaller stars are starved. Thus the size inequity between the large and small stars continues to grow, resulting in undesirable size inconsistency that can only be controlled through frequent screening. Various techniques can be used during rolling to reduce this problem, such as stirring the pile by hand, spraying the drum wall in order to wet the bottom stars and only applying composition to the top edge of the star pile. However, all these techniques slow down the production process and still do not eliminate the need for frequent screening.

An Unconventional Roller Solution:
In my search for the ultimate star roller, I can honestly say that the simple and economical design shown in Figure 8 is also the best performing star roller I have ever used. It's the kind of simplicity that leaves you saying "why didn't I think of that sooner?" Perhaps it is a mental block that prevents us from deviating too far from conventional star roller designs that prevents this kind of thing from being discovered. Anyway, your next star roller undertaking should

begin at your county tire dump, because this is the future of star rolling in my opinion.

Figure 10 shows how the shape of a typical car tire helps guide your sprayer mist to the stars instead of the sides of your roller that you want to remain dry. The 24" diameter tire shown here is rotating at 30 RPM, which is pretty fast for such a large diameter roller. You can start with a cup of very small husked millet cores and have very little problems with them sticking together in the early stages of rolling. The high RPM and ribbed inner tire surface really keeps them bouncing around similar to the way the off-center drive shaft method already mentioned.

I originally believed that the ribbed inner surface found in almost all tires would be problematic and result in composition getting trapped in all the grooves. I went through great efforts to figure out a way to eliminate or fill in this pattern to form a smooth inner surface, only to find out later that the roller actually performs much better as-is! Figure 11 shows how the small ribbed texture eliminates star pile slippage, which would normally be a big problem in large diameter rollers.

The internal ribbed tire texture also tends to circulate stars from the bottom of the star pile and deposit them onto the top of the pile, as seen in Figure 11. This gets rid of the problem previously described where the small stars hibernate at the bottom while the large stars rise to the top. The stars are continually mixed by the tire roller without any effort on the part of the operator. Screening is still required occasionally to remove small stars that form on their own, but no where near as often as required with traditional star rollers. When making the 15 pound batch of 1/4" round stars seen in Figure 9, only one screening was required.

The amount of skill required by the operator to produce consistently sized stars without getting clumps in the early stages is greatly reduced by this roller. Surprisingly, problems with composition sticking to the walls of the tire are very minimal. The only noticeable problem with this type of roller is that it does tend to carry some dry comp up to the top of the tire and drop it down. The falling comp tends to drift outside the tire and collect underneath it, which means care must be taken to isolate the motor from the falling dust.

While this roller does produce slightly more airborne dust than a typical drum roller, it has the advantage of being open to air flow so that a fan can be placed behind the operator to insure that airborne dust is blown out the back of the tire and away from the operator. This works so well that outdoor star rolling can essentially be done without the need for wearing a heavy, sweaty respirator for hours on end!

This design is really nothing more than a variation of a ball mill that takes a large tire as the milling jar. It is very simple and cheap to produce, as described in full detail in this months tool tip. I produced the one shown here in just one weekend using about $80 in materials!

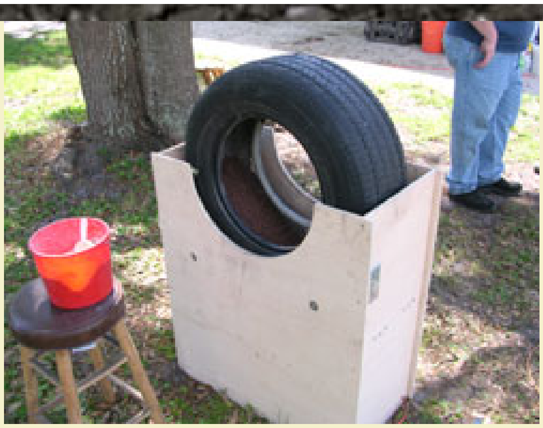
Figure 8: The Passfire star roller using a tire as the rolling drum.

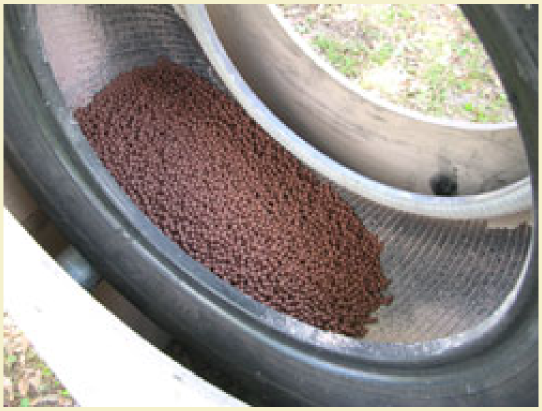
Figure 9: High volume and star uniformity achieved with the tire roller.

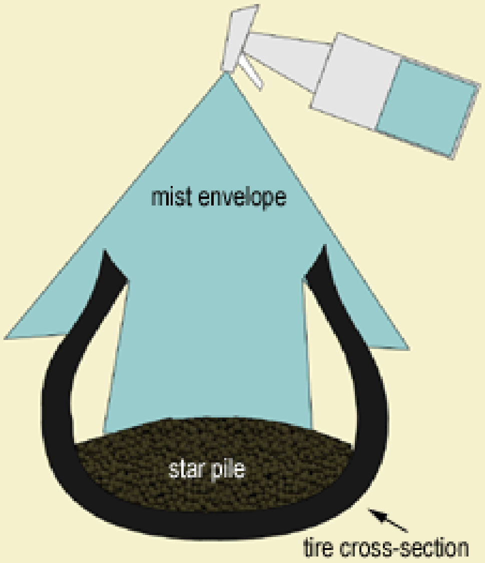

Figure 10: Tire roller greatly reduces misting the container walls.

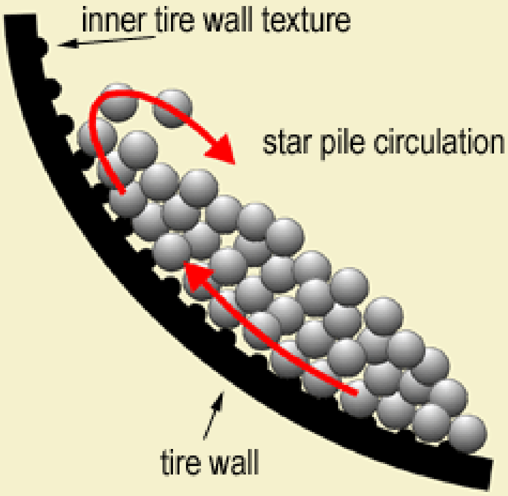

Figure 11: Textured inner tire surface eliminates sliding star piles and circulates stars from bottom of pile.

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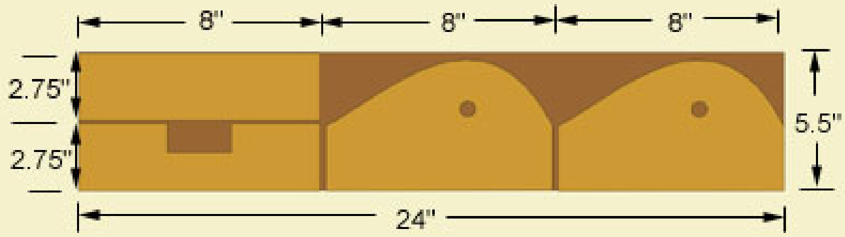
Tool Tip... **Page 1**

Table Top String Dispenser



Materials:

- (1) 24" long 1x6 wood
- (1) 10" long 5/8" dowel rod
- (8) 1-1/4" long #6 wood screws
- (2) 2-3/8" long x 3/4" x 1/8" wood
- (2) 1/2" long #6 wood screws
- (1) Utility knife blade

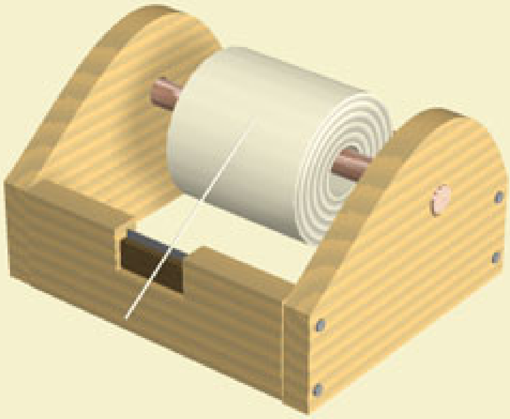


Figure 1: The completed string dispenser.

Introduction:

This is a simple project that is a pretty handy thing to have around if you build a lot of set pieces, wheels, girandolas or other items that require a lot of string ties. Since I can't even think of any pyro devices that don't require string, that would include just about everything!

This tool is modeled after the common household tape dispenser, only modified to work with string instead. The benefit over just working with a roll of string sitting on the table is that the roll isn't prone to rolling off the table, can be unwound easily and best of all, the string can be quickly cut without having to pickup a pair of scissors or a knife. A razor blade mounted on the front edge provides the means to quickly cut off lengths of string

This tool is really handy when you have to cut many strings of the same length, such as when tying many similar sized drivers to a frame. You simply pull the string out to a measured mark on your table, then drop it down on the razor to cut it. It also works great for pre-tying clove hitch knots that will be cut and placed over many tie-points prior to cinching them.

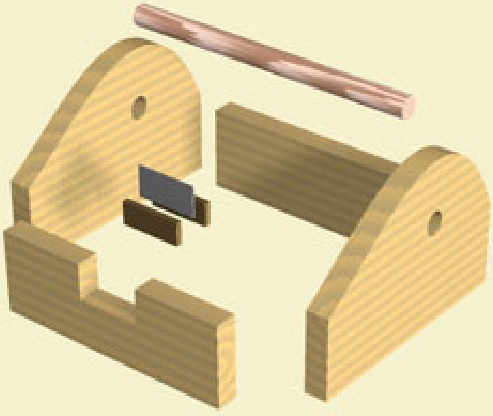


Figure 2: Exploded view of string dispenser parts.

Construction

Construction of the device is pretty straight forward, as no fancy woodworking is required here. You don't even have to round off the side pieces if you want, you could just build a square box and it would work just as well.

A length of 1x6 is first cut into three equal sized pieces that are 8" long. One of these pieces is then ripped in half to produce the front and back sides. The two side pieces are stacked on top of each other and then a 5/8" hole is drilled through both of them, visually positioning the hole roughly as seen in the diagram. The front side is notched to a size that will fit your razor blade, which was 2-3/8" wide x 1-1/4" deep for the blade I used.

The box is assembled by just butting the joints flat against each other with wood glue in between, then clamped and allowed to dry. Two wood screws are then used to reinforce each joint as seen in Figure 1.

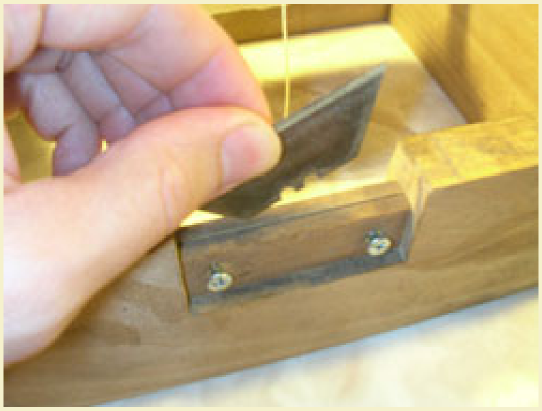


Figure 3: Inserting razor blade between the wood slats.

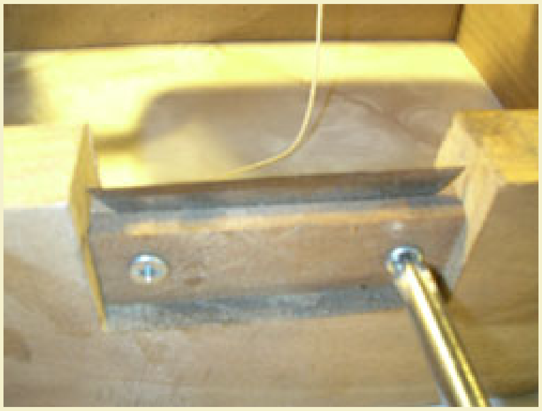


Figure 4: Clamping the blade down by tightening the two wood screws.

A 10" length of dowel rod that matches the hole size you drilled is run through the side holes and just left loose so that it can be removed in order to change out different rolls of string. If it fits so loose that it tends to fall out during use you can always wrap a turn or two of masking tape around one end so that it wedges more tightly in place.

The razor blade is held in place by sandwiching it between two thin strips of wood, which are then clamped together using wood screws as seen in Figure 3 and 4. This design requires that you use a blade with tapered sides rather than the square type of blades, otherwise you would have to cut the wood strips to be longer than the blade so that the screws could avoid hitting the blade. After the blade is clamped, wood glue is palced on the bottom of the wood slats and the assembly is set into the notched hole to dry. Because only the bottom of the wood slats are glued, the screws can still be loosened to replace blades as needed.

One design improvement could be to protect the blade so that fingers can't accidentally be cut on it. I did manage to cut myself on this once while blindly reaching into a box to fetch the dispenser. To prevent this, the blade would have to be enclosed such that it was only accessible through a slot wide enough to permit the string but narrow enough to block a finger from getting in. The trade-off with this safety feature is that you wouldn't be able to make as close of a cut with the finger guard in place. Another alternative could be to just cover the blade with a removable blade guard when not in use.

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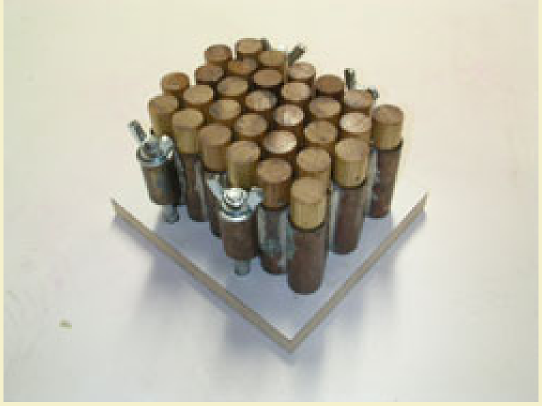
Tool Tip... Page 1

The Poor Man's 3/4" Comet Plate

by ***Kyle Kepley***



Materials:

- (30) 2-1/2" long 3/4" copper tubes
- (4) 1-1/2" long 3/4" copper tubes
- (30) 3-1/4" long 3/4" oak dowel rods
- (30) small 1/2" long nails or tacks
- (4) 4" long 3/8" bolts
- (4) 3/8" wing nuts
- (4) 7/8" O.D. washers
- (1) 7" x 6" scrap of 3/4" plywood
- (1) 8" x 8" scrap of Formica
- Solder
- Flux
- Polyurethane

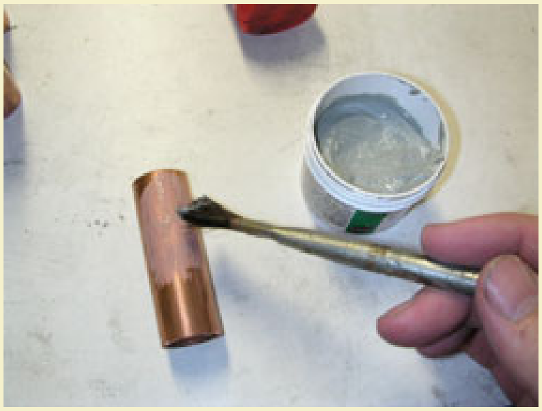


Figure 1: Brushing flux onto a pipe segment before soldering.

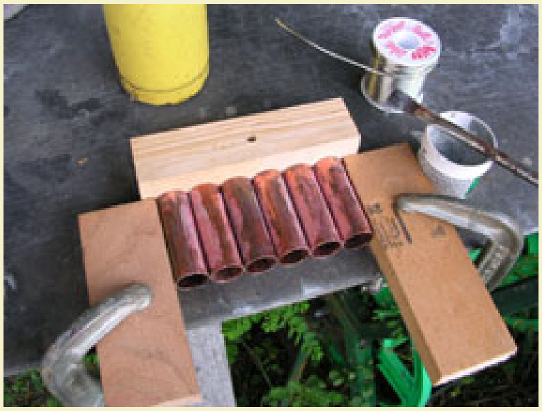


Figure 2: Squaring up a row of tubes to be

Introduction

Anyone who has ever built a large multi-break Maltese or Italian shell can attest that at least half of the construction time was spent painstakingly pumping out comets one at a time. It takes about 342 3/4" comets to make one three break six inch multi-break shell, and pumping these out one at a time takes over three hours of tedious monotony.

Comet plates are simply large caliber star plates that allow multiple comets to be produced in one operation. However, the larger size requires thicker blocks of metal and longer drilling times to produce, thus a typical 3/4" star plate costs several hundred dollars if purchased from a pyro tool supplier.

Some pyros who are handy with machine tools and have lathes and milling machines at their disposal have produced their own comet plates, but even with the right tools on hand it is not a trivial task. Traditional comet plates use large blocks of aluminum as the hole plate, with many pins that must be machined on a lathe and then fastened to another thick plate using set screws for each pin. The pin holes must be drilled and then bored out with a special bit to insure that the walls are smooth so that the comets can slide out easily.

Most pyros can not afford a commercial comet plate and do not have the means to build their own. When pressing dozens of large comets at one time, even having the proper plate set is not enough. You must have a hydraulic press to adequately compress many large comets at one time, and you also need some type of holding fixture so that the comets can be pressed out using the press ram once they have been consolidated. Needless to say, the setup for producing soldered together.

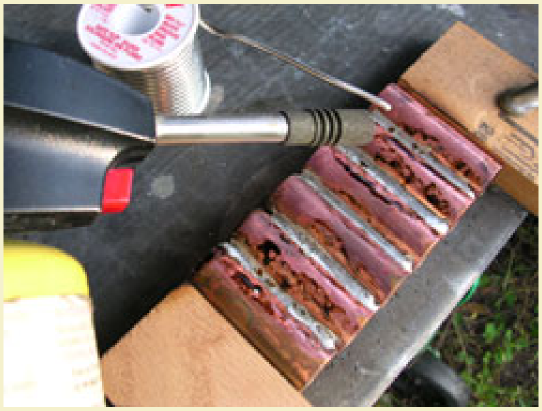


Figure 3: Using a blowtorch to run a bead of solder between each pipe.

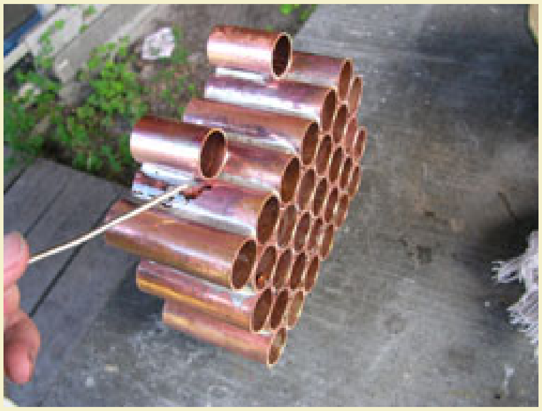


Figure 4: Soldering the shorter clamping tubes to the sides.

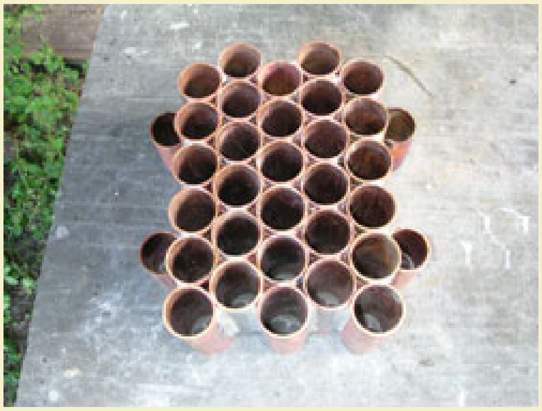


Figure 5: The finished tube block for pumping 30 comets.

large volumes of comets is out of reach for most pyros.

The project shown here is a poor man's comet plate that can be easily made by most anyone. The parts are available in almost any hardware store, and the whole thing can be built for under $30. No special machinist skills are required and it can be fabricated using only hand tools, although a cut-off saw makes the task of cutting all the tubes and dowel rods to the same size a lot easier and faster.

The plate design uses commonly available copper plumbing pipe to provide the pressing sleeves, thus removing the need for drilling large holes in thick, expensive blocks of metal altogether. The use of thin walled pipe soldered together into a block also produces a denser grouping of holes than could be produced by drilling, so the resulting hole plate is more compact and easier to fill with composition.

The user of copper tubes also allows you to have exact control over the thickness of your hole plate. You can run experiments with various lengths of tubes to see what heights the compositions you plan to pump will compress into. This way you can make a plate that produces stars of the exact height that you want. Those who build traditional star plates are limited by whatever blocks of aluminum they happen to find at the scrap yard, and the thicker chunks of metal are more difficult to find (not to mention expensive).

The pin plate is not a plate at all, rather just a bunch of loose pins inserted into the holes. This simplifies construction by removing the difficulty of aligning many pins with many holes, and also removes the chore of securely fastening many pins to a pin plate. Another benefit to this simplicity is that the pins can be made from whatever material you can find that will withstand medium blows from a hard rubber mallet. Commonly available oak dowel rods were found to sufficiently fit inside the copper tubing and hold up quite well to pounding.

The independent pin design featured here also allows the comets to be consolidated by hand ramming, which is not possible with a traditional plate of the same size. Because the pins are not all attached to a common pin plate, a mallet can be used to apply force to each pin independently. A traditional comet plate, where all the pins are connected to a common top plate, will take any force applied to the top plate and distribute it equally to all pins. This makes hand ramming a large caliber comet plate ineffective and a hydraulic press is required. The plate shown here allows all the force from a small rubber mallet to strike just one or two pins at a time, thus each comet gets the full brunt of the ramming force. As the comets are pressed, those that are compressed less than others will have their pins sticking up higher, thus the mallet will hit them first until they are level with the others. This feature insures that the comets in most need of compression get the most impact from each blow, until such point that all pins are rammed evenly.

This comet plate also works equally well when used with a hydraulic press. Simply place a thick block of scrap metal on top of all the pins to serve as a pressing plate, then insert it into your press and compress all pins at once the same way you would with a traditional

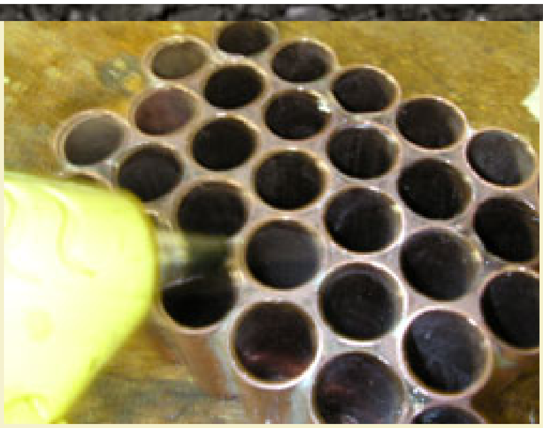


Figure 6: Using hot glue to fill in the voids between pipes.

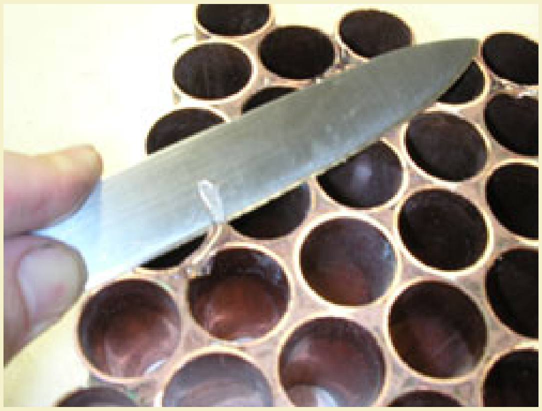


Figure 7: Shaving the solidified glue flush with the surface.

comet plate.

Another advantage of this independent pin design is that the comets can be pressed out of the bottom plate without the need for a hydraulic press or heavy blows from a mallet. When pressed individually with your fingers, the comets will slide right out! Simply hold the filled plate by the finger holds on the sides while rapidly pressing the comets out one at a time by pushing the pins down with your thumbs.

The only disadvantage with the independent pin design is that it is slower to setup than a traditional plate, since you have to place the pins into the holes one at a time rather than just positioning a single plate on top that inserts all the pins at once. Ditto for removing the pins after the comets have been pressed out. So it's a little slower than a traditional plate to operate, but still markedly faster than pumping single comets out one at a time and a lot easier to build and operate for the average pyro on a tight budget.

More...

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The Poor Man's 3/4" Comet Plate...

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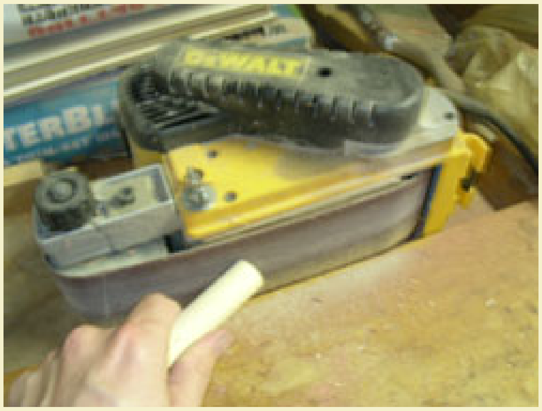

Figure 8: Cleaning up the edges of an oak dowel rod.

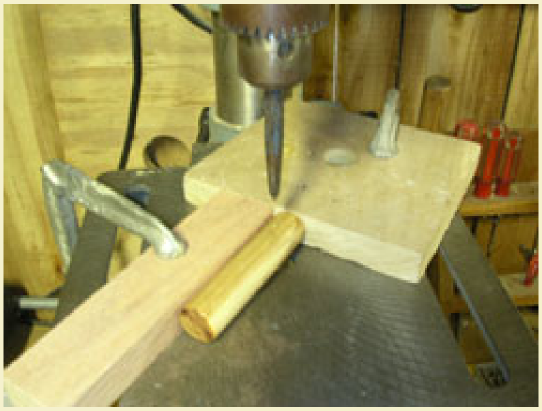

Figure 9: Using a jig to consistently mark the nail position on all pins.

Making the Hole Plate:

The plate shown here is designed to pump 30 comets in five rows of six tubes per row. This is a somewhat arbitrary number and you can easily change it to whatever size array that you want. You can even add onto the capacity at a later date by simply soldering on more rows of tubes and making more pins.

The copper pipe being used here is common 3/4" plumbing pipe available at almost any hardware store. The I.D. is slightly larger than 3/4", but it is close enough to work well. The tube length shown here is 2-1/2" long, but you should experiment with the compositions you plan to use most often for comets before committing to a tube length. I used metallic KP formulas heavy in parlon for my own trials, with a resulting star height of about 3/4".

The trials are conducted by dampening the comp, running it through window screen and then filling the tube with loose grains until it is full. Do not compress the comp into the tube with your fingers, just loosely fill it the way you will be doing when you use the plate. Then hand ram a single pin with a mallet and measure the height of the resulting comet. If it is too short then try a longer tube, or if it is too tall then try a shorter tube.

Once you determine your tube height, you will need to cut 30 tubes to that length. This can be pretty tedious without a cut-off saw, also known as a horizontal band saw. This is probably one of the most useful power tools for the pyro hobbyist that there is, so if you haven't looked into getting one yet I would seriously recommend one. It's going to save you from making 60 cuts in just this project alone!

Once the tubes are all cut, de-burr the inside edges with a de-burring hand tool and then clean up the outside edges with sandpaper or, even better, using a power sander or bench mounted grinder. Make sure the outside of each tube is free from grease and debris before proceeding.

You will be soldering these tubes together in groups of six using a blowtorch and plumbers solder. You will also need to obtain some soldering flux, which is a grey paste that is brushed onto the areas to be soldered as seen in Figure 1.

Build a temporary fixture for holding six tubes together as seen in Figure 2, with a block of wood used to butt all the ends against so they are level. Brush the flux on the tube walls at the point where they touch each other. The tubes will get very hot, so make sure the

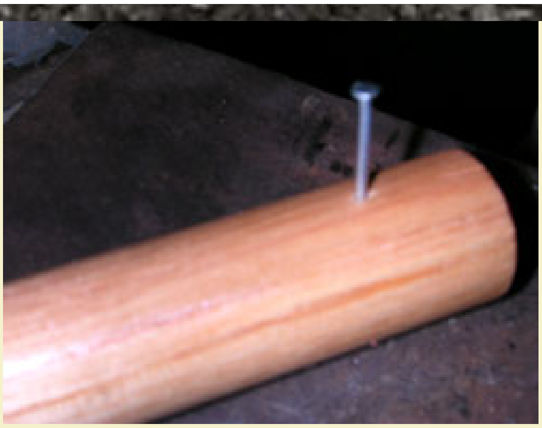

Figure 10: Driving a small nail to be used as a depth stop.

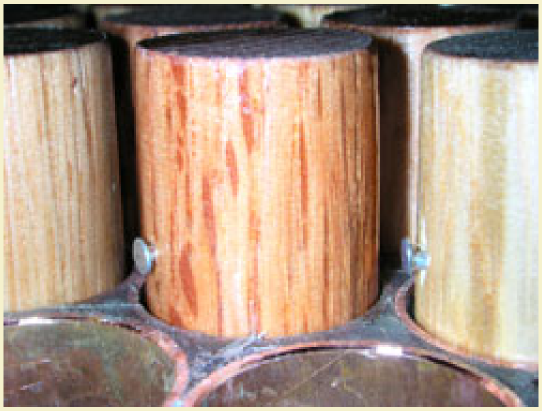

Figure 11: Nail prevents pins from falling all the way through the tube when comets are pressed out.

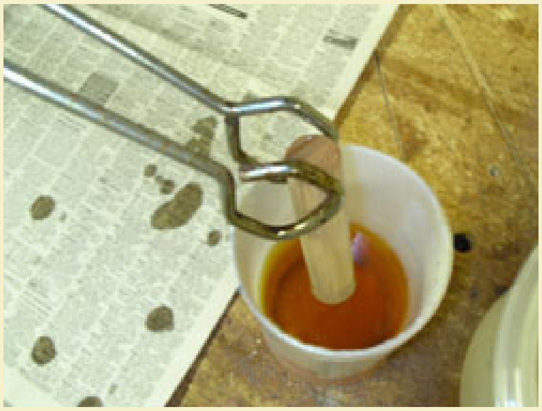

Figure 12: Dipping the pins in polyurethane for water resistance.

surface you are working on will not get damaged by heat. The table top shown in Figure 2 is a 1/2" thick piece of cement backer board.

A blowtorch is now used to "sweat" a bead of solder between the joints of each tube, as seen in Figure 3. The solder goes through two phases before the job is done, so be careful not to remove the heat prematurely. At first the solder will melt, but still bead up on the surface and not adhere to the metal. Continue applying heat until the surface tension of the solder breaks down and flows smoothly into place.

Once the joints are soldered, wait a few minutes until they solidify, then use BBQ tongs to dunk the hot metal into a bucket of water. This process is repeated four more time so that you have five separate rows of tubes.

Once the five rows are completed, they are stacked together and clamped using metal bar clamps. This assembly is then turned on its side and a bead of solder is used to connect the outside edges together. There is no way to solder the inside joints, so be sure that you do a good job on the outside joints. Once finished, dunk the unit in water again to cool it off.

Next you will need to attach four shorter pieces of pipe to the long sides, which will be used as both finger holds when ejecting stars and for clamping the fixture down to an optional hold-down plate. Rest the block of tubes on its side and attach the shorter tubes with a bead of on each side as seen in Figure 4. The completed tube assembly is shown in Figure 5.

If the tubes are not all even on both the top and bottom of your hole plate, use a sanding block to work down the high spots and level it out.

The voids between the tubes are now filled with hot glue, as seen in Figure 6. If these voids are not filled, powder will fall into the cracks and make a mess during use, so you really should plug the holes. The gaps on both the top and bottom sides should be filled. It helps to pre-heat the copper block with your torch prior to applying the glue, which helps the glue settle into the crevices rather than beading up on contact. Once all the cracks are filled with glue, dump the unit into a bucket of water so that the glue will solidify quickly.

Once the glue is hardened, shave off the excess using a thin knife as seen in Figure 7. This should give you a smooth surface that is free of pinholes and gaps. If you missed some spots, just reheat the area with a torch, apply more glue and then trim it again. Be sure to clean up any glue that leaked down into the tubes.

Making the Pins:
A pin that is about one inch longer than the tube length needs to be made for each hole in the plate. You can use wood, metal, plastic or anything that can take a beating. I'm using oak dowel rods here because they are cheap and easy to find.

After the pins are cut, sand the top and bottoms smooth and de-burr the edges. A small nail is driven nearly all the way into one end of the pin as seen in Figure 11, which is to prevent the pins from dropping all the way through the plate when the comets are ejected. The nail should be located about 1/4" above the top of the tube when the pin is inserted, which will allow the pin to project out the bottom of the plate by 1/4" after the comet is pressed out.

More...

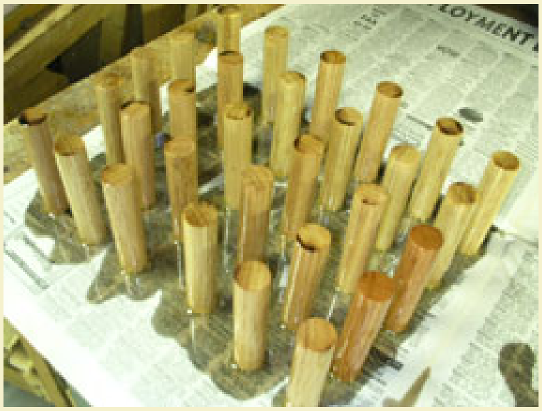

Figure 13: Drying the pins on a sheet of newspaper.

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The Poor Man's 3/4" Comet Plate...

Because there are 30 nails that have to be positioned, it helps to create a jig for marking the nail positions. Figure 9 shows how a drill press with some blocks clamped to the drill stand can be used to mark the nail positions. A center punch is chucked up in the drill while the boards hold the pin in the desired position so that all pins will be marked in the exact same spot.

When using wooden pins, you'll need to coat them with a moisture barrier so that they will not absorb water and chemicals into the grain. Since the pins will be subjected to water when cleaning after each use, you need to use something that can hold up to water at least on a short term basis. I'm using polyurethane here, which is easy to apply by simply dunking each pin into a container of urethane as seen in Figure 12. Each pin is fully submerged into the urethane and then placed on a sheet of newspaper to dry. This process should be repeated at least two times in order to get a good coating.

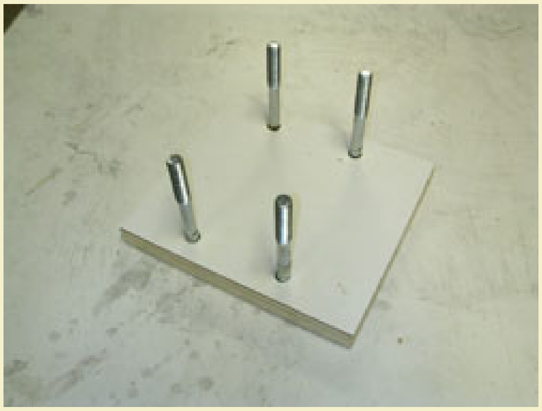
Figure 14: Building the optional hold-down plate.

Hold-Down Fixture:
At this point your comet plate is completed and ready to use. However, you may wish to make the optional hold-down fixture seen in Figure 14. Certain types of composition, such as those heavy in parlon and metal dust, require a good deal of moisture before they can be used to produce comets without crumbling. This overly wet type of composition tends to ooze out the bottom of the plate during ramming and will actually spread out under the plate such that it lifts it right off the working surface. The hole plate literally begins to rise up on top of a bedding of composition that squeezes out the bottom as it is being rammed, resulting in inconsistent comet sizing and a big mess that has to be shaved off the bottom before ejecting the comets.

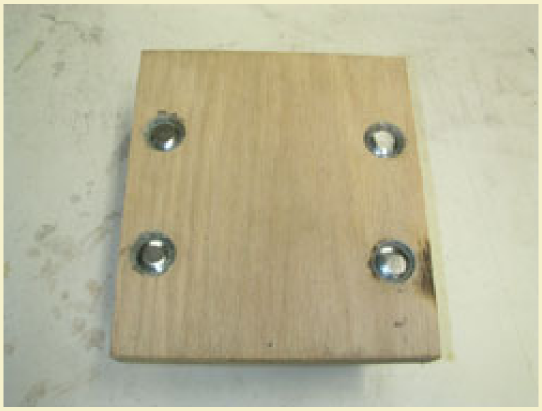
Figure 15: Bolt heads are counter-sunk into bottom of plywood.

The hold-down fixture eliminates this problem by firmly securing the hole plate to the working surface. If you will be using a hydraulic press to pump your comets, then the hold-down fixture is highly recommended regardless of the type of composition being pumped. While it does add an extra setup step, the hold-down plate insures that overly viscous compositions or bouncing during hand ramming does not result in composition working its way out the bottom of the tubes.

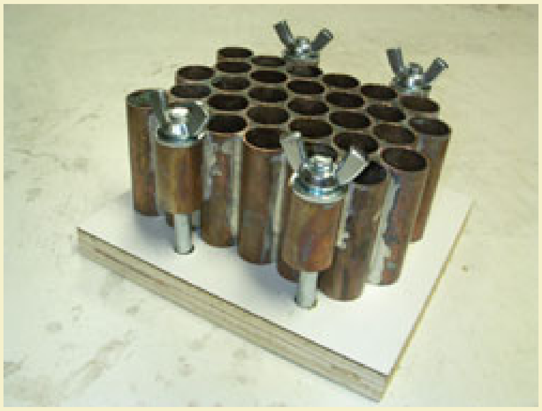
Figure 16: Hole plate fastened to the hold-down plate.

The hold-down fixture uses four bolts to tightly secure the hole plate to a piece of wood that it will be rammed against. The bolts run through the four finger holds that were soldered to the sides of the hole plate, as seen in Figure 16. A washer and wing-nut is used to cap each bolt and fasten down the hole plate. The wing nut tends to get in the way of the pins however, so you may choose to use just a regular nut instead and keep a nut driver on hand when working.

The base of the hold-down fixture is a scrap of 3/4" thick plywood with a sheet of Formica glued to the working surface so that it can be easily cleaned. The bolt heads are counter-sunk into the bottom of the plate, making sure that the heads do not protrude above the surface of the plywood. I used hot glue around the bolt heads to help keep them in place, since I was unable to find long bolts that were threaded all the way up to the heads. If you can find fully threaded bolts, a nut could be used on the other side to fasten the bolts securely in place.

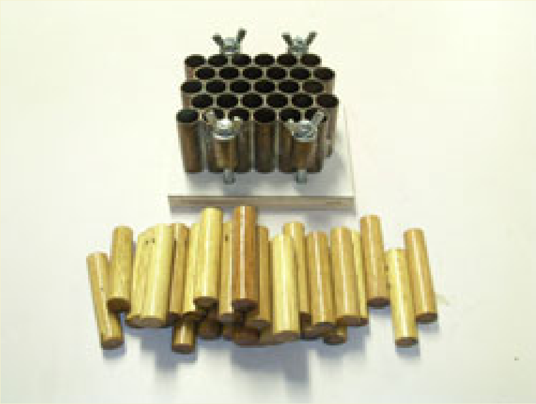

Figure 17: Completed components of the comet pressing tool.

Usage:
This type of comet pump requires the composition to be granulated through a window screen and then loosely filled into the holes. The composition should not be overly damp such that it clumps together after screening, since it needs to free flow into the hole plate. The composition Is not pressed into the tubes in any way, it is simply spread across the surface of the hole plate and allowed to drop in. Any excess is scrapped off the surface with a thin blade and reused in the next pressing. This method of loading is not only faster than pressing composition in by hand, it more reliably deposits the same amount of composition in each tube.

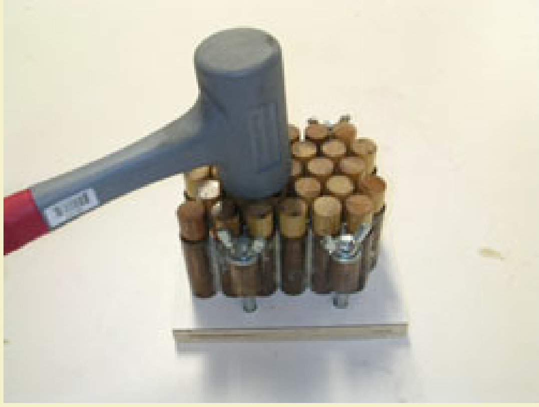

Figure 18: Using a hard rubber mallet to prevent damage to wooden pins.

Once loaded, each pin is pressed into place and then rammed with a rubber mallet as seen in Figure 18. The mallet should be the hard rubber or plastic type, as a soft rubber mallet will not compress the comets enough. A brass hammer could also be used if you are careful about controlling how hard you hit the pins and be careful to avoid glancing blows off the sides of the pins.

Once all the pins have been rammed down to the same level, the comets are ready to be ejected. Check the bottom of the hole plate and make sure there is no excess composition that needs to be shaved off. Failing to shave away excess composition can result in inconsistent comet sizes and sloppy edges.

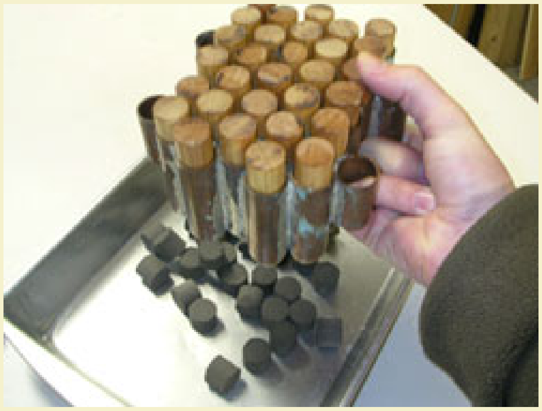

Figure 19: Individual pins allow comets to be pressed out by hand.

Traditional comet plates are placed on a stand-off fixture similar to Figure 20 when the comets are being ejected. The plate fits down between the two side walls such that the bottom of the hole plate is held about an inch above the surface.

Since this comet plate features individual pins, you can easily pump the comets out one at a time while holding the plate above your catch pan, as seen in Figure 19. Normally you would hold the plate with both hands and use both thumbs to rapidly eject the comets one by one. The smooth copper tubing really releases the comets quite easily.

Figure 21 shows how the comet plate can be used with the home made press described here. The only extra thing you need is a thick block of metal to place between the pin heads and the bottom of the bottle jack. The hand-rammed comets are still tough enough that they can't be broken in half by hand when dry. However, hydraulically pressed comets are even more durable and, because they are denser, will burn slightly longer than hand rammed comets.

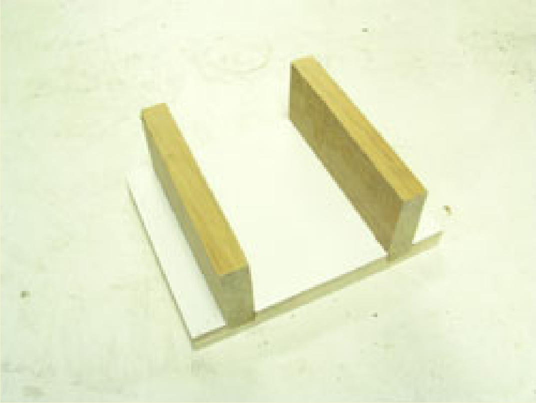

Figure 20: Optional pressing stand-off fixture.

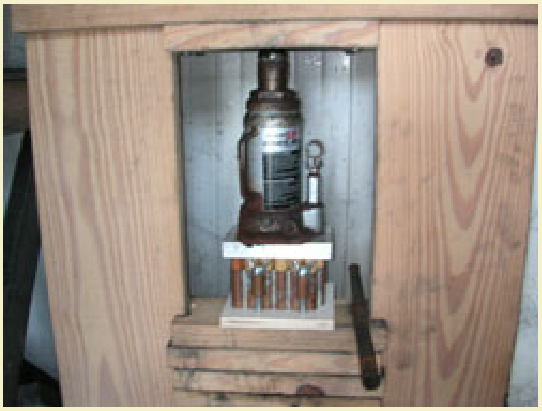

Figure 21: Using the comet plate in a home-made press for creating rock-hard comets.

A little time and effort invested in building this tool will easily pay for itself in saved time and drudgery after only a few large multi-break projects. The low construction cost and ease of fabrication really brings efficient comet pressing to the masses!

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Tool Tip...

Page 1

The Ultimate Star Roller

by ***Kyle Kepley***

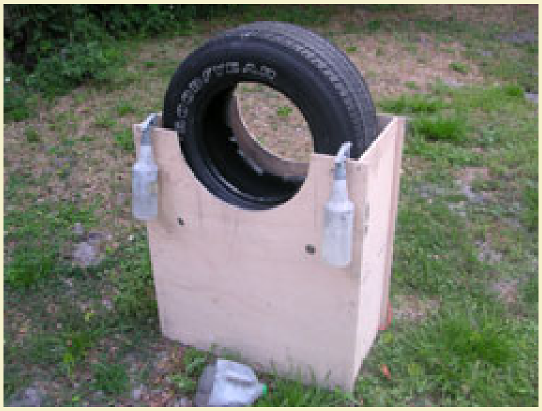


Figure 1: The Passfire Star Roller, also known as the "NASCAR Roller"

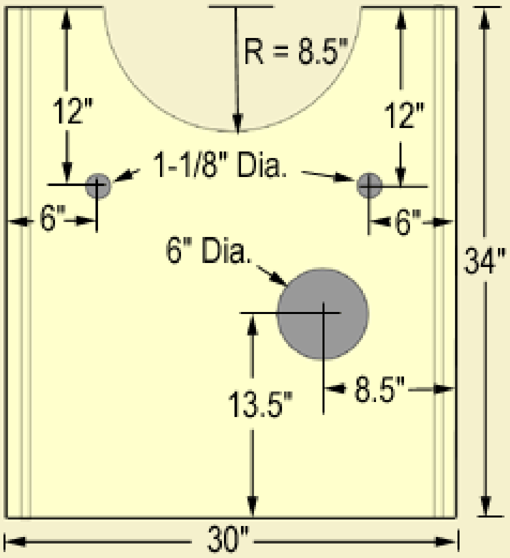
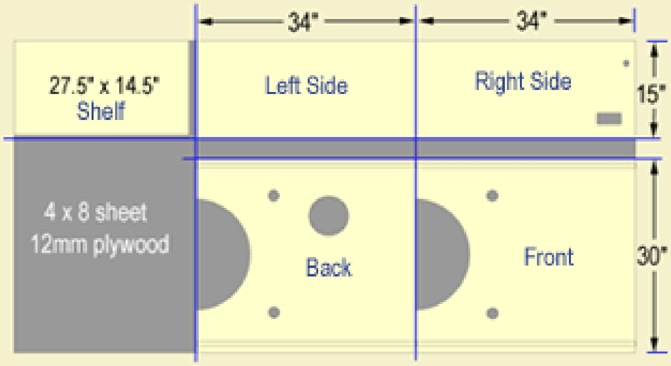


Figure 2: Measurements for front and back panel.

Materials:

- (1) 4'x8' sheet 12mm plywood
- (4) 18" long x 1.5" square pine
- (1) 15-1/2" long 5/8" steel rod
- (1) 17" long 5/8" steel rod
- (4) 5/8" ball bearings (stamped)
- (4) 5/8" shaft collars
- (2) 11" segment 5/8" I.D. heater hose
- (1) 6" v-belt pulley (5/8" I.D.)
- (1) 3" v-belt pulley (1/2" I.D.)
- (1) V-belt 4L-300
- (4) 1-1/2" long 1/4" bolts
- (4) 1/4" wing nuts
- (32) 1-1/4" long #8 wood screws
- (2) 3" gate hinges
- (4) 1" swivel casters
- (1) Switch box w/switch and cover plate
- (1) grounded extension cord
- (1) 1/6 HP 1725 RPM AC motor
- (1) roughly 26" diameter x 10" wide car tire



Introduction:

I recently took this star roller on "tour" this month and, as all agreed who saw it in action, rolling stars in a tire is the future of star rolling. As explained in this months star roller design article, a typical car tire provides a rolling geometry that makes the job considerably easier than a conventional bucket type roller. The surface texture inside a tire provides excellent traction to eliminate slippage that would otherwise be a problem with such a large diameter roller, and also helps circulate stars from the bottom of the pile to reduce the size consistency problem that plagues star rolling. Star clumping is also reduced in the early stages of rolling, and problems with composition sticking to the tire wall is surprisingly minimal. During use there is no need to apply composition to certain areas among the stars, mix up the stars by hand, wet the container wall or any of the other tricks of the trade required to coax good size consistency out of a bucket type roller. The reduced technique not only makes star rolling easier to learn for a beginner, it also speeds up the process as well!

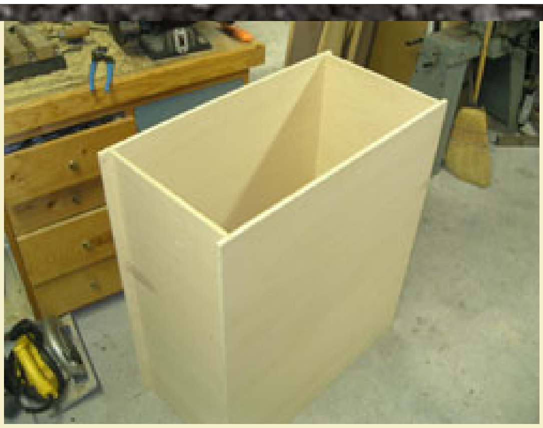


Figure 3: Starting with a basic box.

Other than the concept of rolling stars in a tire, there is nothing all that special about the design shown here. It is simply a box with two rollers, similar to what a large ball mill might look like. You may be tempted to shorten the box walls around the tire to save wood and expand the range of tire sizes the box can accommodate. There are two potential problems with doing this: the taller box walls insure that the tire can never topple off the rollers if it ever gets bumped or becomes unbalanced during use. The taller box walls also allow the standoff-casters to be located higher up the tire wall and off to the sides as seen in Figure 13, keeping them away from the powder drop zone directly under the tire. Using short box walls would force you to place the caster as seen in Figure 14, which would be subjected to falling powder. This would not only clog up the bearings, but also subject the powder to a friction point between the caster and the tire wall, resulting in a possible ignition hazard.

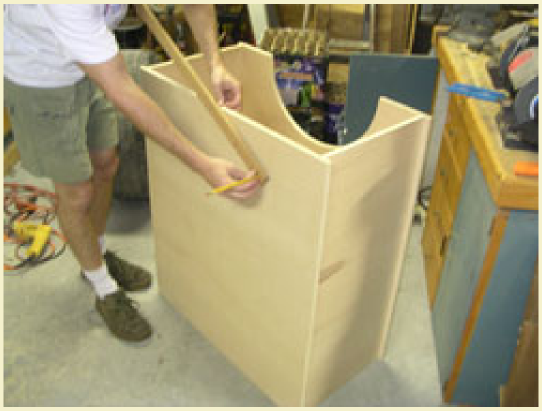


Figure 4: Using a home-made compass to mark the circular cutouts.

One important thing to remember if altering this design is that the tire will drop more composition than a bucket type roller, due to having two open sides instead of one. Thus the motor must be completely insulated from falling powder, and something needs to be placed under the roller to catch the spilled dust.

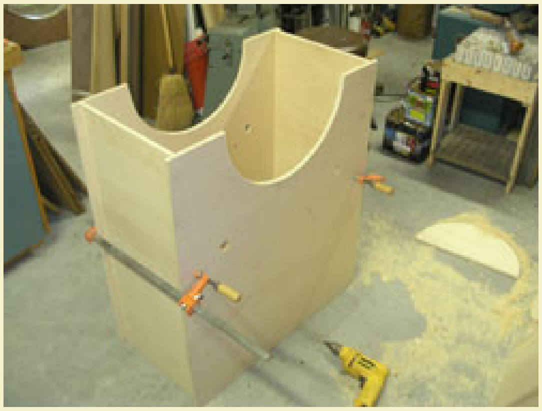


Figure 5: Holding box together with clamps while fitting-out internal components.

Building the Roller:
Due to the escalating cost of good 3/4" sanded plywood, I have opted to use a thinner multi-ply "Guatambu" hardwood that can now be found in most lumber yards. This imported wood comes in various metric thicknesses, and is very smooth and defect free. The 12mm board used here is about 7/16 inches thick, which is a little on the thin side for a machine cabinet but will work due to the reinforced corners used here.

The easiest way to cut the sheet into the pieces shown above is to use a panel saw. Since most people don't have one of these at home, you can have the lumberyard cut it up for you (even Home Depot will do this). First cross-cut the two 34" wide pieces, then rip a 30" and 15" piece from each of the 34" panels. The remaining scrap will be used for the shelf, but it is better to measure and cut this piece after the cabinet has been assembled just in case

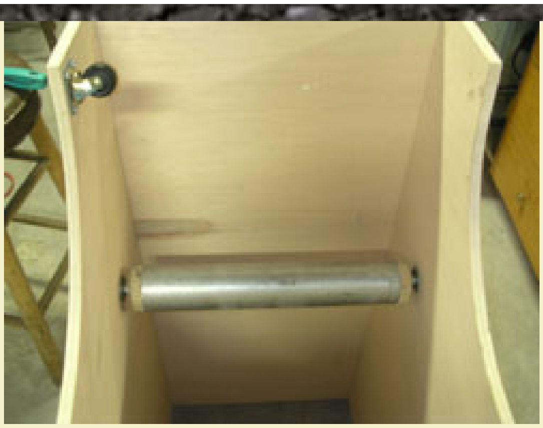


Figure 6: Idler roller installed. Note the caster to prevent the tire from contacting the cabinet.

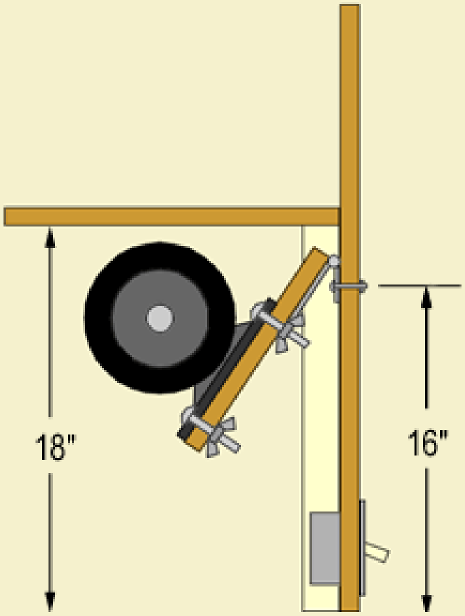


Figure 7: Details of right panel hardware.

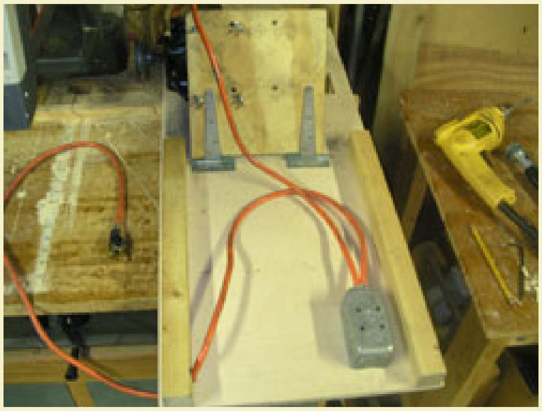


Figure 8: Motor and switch wiring.

your dimensions are slightly different. The shelf needs to have a good fit so that powder can not leak around the edges.

Figure 2 shows the layout of the front and back panels, which are identical with the exception of the 6" diameter motor access hole in the rear panel. This cabinet uses dado joints, which is a type of joint where one piece of wood fits half way into an adjoining piece. This requires a channel to be cut half way through the inside faces of the front and back panels, located 3/4" from the left and right edges and running the full height of the panel. The width of this channel is just a hair wider than the plywood thickness so that the side panels can slide into it and lock in place. A router or dado blade can be used to do this, but if you don't have the tools then you can probably get away with just butting the pieces up against each other and using the corner blocks shown in Figure 13 to hold them together.

If you decide not to use dado joints on the box, you will need to either subtract 1/2" off the side panel width or add 1/2" to the length of both steel roller bars. It would also be a good idea to fasten a 3/4" square strip of pine along both inside edges of the front and back panels, which will help you align the pieces when assembling the box.

Figure 3 shows the box pieces locked together for a trial fit. No glue is used to fasten the pieces together, since you will occasionally have to disassemble at least one panel to service the rollers and motor. Only four #8 wood screws are used on each edge of the front and back to hold the panels together.

Figure 4 shows a make-shift compass used to mark the semi-circle cutouts, which consists of a piece of wood with a hole that holds a pencil. A small nail hammered through the pivot point is held against the edge of the board as the line is drawn. This is easier to do before the panels are assembled and Figure 4 is just for illustration. A jig saw is required to cut out the half circles.

The 5/8" bearings used in this project will fit snugly into a 1-1/8" hole. Stamped bearings are not only cheaper than other types of ball bearings, but the metal flange around the rim of the bearing is ideal for holding the bearing in place. The bearings will be inserted from the inside of the panels and locking collars on the roller shaft will butt up against the bearing and hold the whole assembly in place (see Figure 12). Thus all you need to do is drill two 1-1/8" holes in the front and back panel, as marked in Figure 2. The 6" motor access hole should not be cut until after the internal parts are fitted out so that you

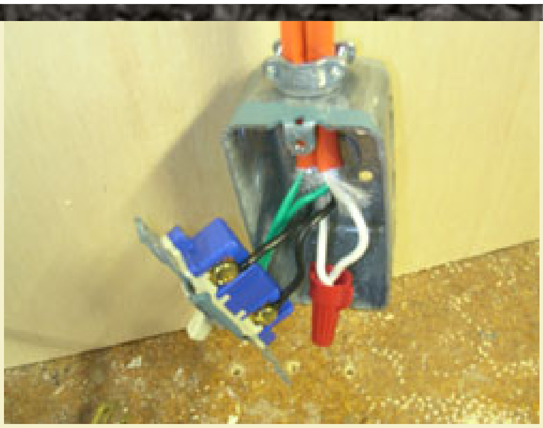


Figure 9: Closeup of junction box wiring.

will be able to know exactly where to center it. The placement shown in Figure 2 will only be right if you use the exact same motor and belt size as I used, which is unlikely.

Once the front and back panels are cut and finished, stand them up and fasten them to the left side panel and right side panels, using bar clamps to hold them together while you drill and drive the screws as seen in Figure 5. Next you will square up the box and attach the 1.5" square corner braces into each corner, securing them with screws running through the panel and into the braces on both sides.

Next you will need to remove the right side panel so that you can install the motor and switch hardware. Remove the screws that hold the corner braces to the front and back panel so that they will remain attached to the side panel when you remove it. The motor and switch hardware are now mounted to the inside of the right panel as seen in Figures 7 and 8. The switch is mounted low to the ground so that it can be operated by your foot.

Begin by drilling a 1/2" hole in the lower left corner as seen in Figure 7. Feed your extension cord through this hole first, then wire it to the switch box as seen in Figure 9. Cut a 1-3/8" x 2-5/8" square hole in the lower right corner to accommodate the switch. Your switch box will have mounting holes that are probably about 3-1/2" on centers, so you will need to drill holes below and above your square cutout for the mounting screws to pass through from the outside.

More...

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Ultimate Star Roller...

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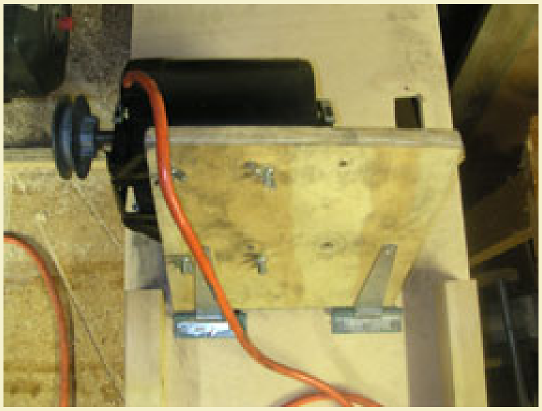

Figure 10: Closeup of motor mounted on hinge plate.

A segment of the extention cord is cut off prior to wiring up the switch, which will run from the switchbox to the motor. The motor used here can be wired to allow both clockwise and counterclockwise rotation. For right handed people, a star roller should rotate in a clockwise direction, which means the motor should also be wired for a clockwise rotation in this case. A clockwise rotation puts the star pile on the left side of the roller, making it easier to spray with your right hand. Left handed people will want a counter clockwise rotation instead.

The motor for this project is a 1/6 HP AC surplus motor running at 1725 RPMs. This motor, which was purchased at www.meci.com, has a nice mounting bracket on the bottom for attaching it to the hinge plate. The hinge plate is a 9-3/4" long x 9" wide piece of plywood with four holes dilled to match the motor mount plate. Four 1/4" bolts with wing nuts are used to fasten the motor to this plate. Two gate hinges are used to attach the motor assembly to the panel wall, as seen in Figure 10. Note that the motor is installed as far to the left edge of the panel as possible without it rubbing against the back panel when installed. The motor shaft needs to extend far enough out the back of the box for you to get a pulley wheel on it.

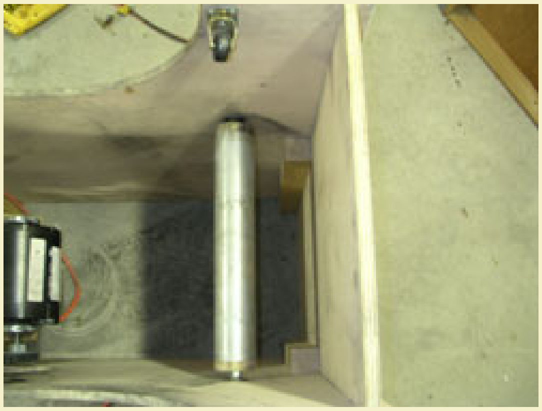

Figure 11: Shelf supports fastend into corners.

The panel is now fitted in place so that you can figure out where to cut your access hole in the rear panel. Attach the front panel first, leaving the rear panel unattached. You will need to insert the drive shaft into the front panel and hold up the pulley end so that you can hang the motor from it and see where the center point of the motor shaft will be on the rear panel. The location doesn't have to be exact, since the 6" diameter hole leaves some room for error.

Once you know where your motor shaft will need to exit the rear panel, detach the rear panel and cut the 6" access hole at the point you marked. The rear panel is then re-attached and all screws holding the edges and corner braces of all panels are now firmly secured.

At this point you are ready to fit out the inner shelf board. Figures 12 and 13 shows this board installed. The inside dimensions of the box are now measured and a piece of leftover plywood is cut to exactly fit this hole. The shelf can be dropped in place without any need to fasten it to the corner supports, or you can drive a screw into each corner to hold it down.

The idler roller shown in the pictures here is actually a leftover from the Maltese shell roller project and not necessary. This kind of roller is actually more difficult to work with because you can not install it after the box is closed up. It must be installed at the same time the box is being closed, while the drive shaft type rollers can be installed or removed without having to open the walls.

Both the idler roller and the drive roller are constructed from 5/8" steel rods with 11" segments of rubber heater hose slipped over them. It is important not to make the heater hose segments longer than this or you may not be able to install the rollers without opening the box. The trick to pushing the tight-fitting heater hose down onto the middle of the roller bars is to use a tube that just fits over the shaft but does not fit over the heater hose. The hose is pressed onto the shaft by hand until it is flush with the edge, then the pipe is placed over the end and a mallet is used to drive it the rest of the way onto the shaft. An alternate method is to drill a 3/4" hole in a piece of wood, place the shaft on end with the heater hose side down, then hammer the shaft down through the hole until the hose is in the right place.

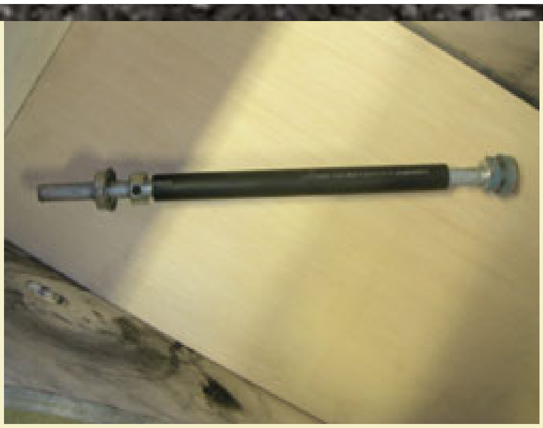
Figure 12: Drive shaft ready for installation after shelf is dropped in place.

Install each roller as follows: Take the roller shaft and slip a shaft collar on each end, followed by a bearing. The flange end of the bearings should be facing each other, as seen in Figure 12. The collar on one end is locked down so that it holds the bearing at the end of the shaft. The bearing and collar are left loose on the other end, and this end is slipped into the mounting hole from inside the box. There should be enough room to slide the other end of the shaft into the hole on the opposite side. The loose bearing is now slid down the shaft and pressed into its hole, then held in place by tightening down the remaining shaft collar.

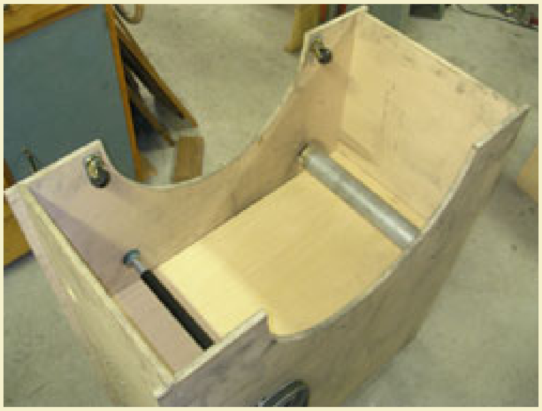
Figure 13: Shelf and rollers installed. Note the swivel casters on each side of the cutout.

Because a tire has the ability to travel back and forth on the rollers, you will need to put swivel casters on the inside wall of both ends. These casters will provide a low-friction stand-off to keep the tire from rubbing the front edge. For reasons already discussed, do not be tempted to use a single caster as seen in Figure 14 as an alternative to the caster arrangement shown in Figure 13.

The roller box is finished out by adding the pulleys to the drive shaft and motor as seen in Figure 15. The pulleys shown here are a 6" and a 3", but any combination that results in a 2:1 ratio can be used. In fact, a 4" and a 2" would be more desirable, since it would be cheaper and also gives more space between the pulleys to allow larger diameter motor pulleys to be used when dropping the RPMs for larger stars. For example, you could cut the rolling speed in half by using a 4" pulley on both shafts, while two 6" pulleys would not be possible with the dimensions shown. Smaller pulleys also result in less position change in the hanging motor when changing speeds, allowing the motor to stay in the cutout hole area without having to change belt sizes when pulley sizes change.

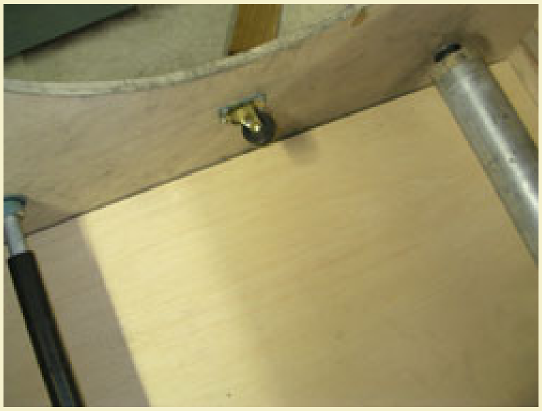
Figure 14: A single central caster is tempting but should be avoided as a potential hazard.

While this cabinet was designed specifically for a Goodyear Eagle GT tire that is about 26" Diameter and 10" wide (P255/60R15), it will work with any type of tire that is right around this size. One drawback to partially closing in the tire with the cabinet is that you can't use a bigger tire than this, but you can certainly use smaller tires. If you plan to use smaller tires, you may need to build your rollers closer together or drop the shelf height to keep the smaller tires from coming into contact with the dust collection shelf. It is best to obtain the tire or range of tires you want to use first, then alter this design to work with your tires.

A trip to your local city dump should allow you to choose from a very large range of tires to use for your roller. I prefer a tire with a deep, rounded inner volume for holding lots of stars. The inner surface should have small ridges, but avoid too aggressive or pitted of a surface and look out for defects as well. The nice thing is that your roller drum is free, so if it doesn't work out then pitch it and try another one. You can also keep one tire for chlorates and a separate tire for non chlorate mixes.

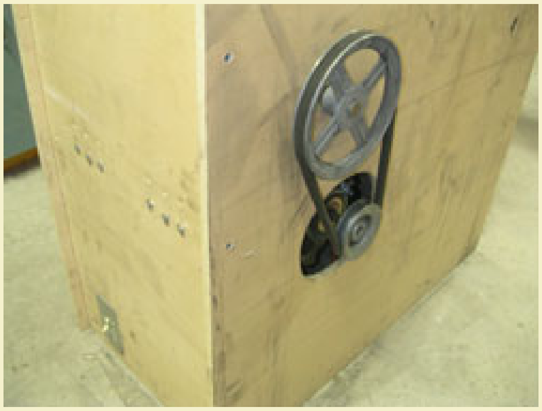

Figure 15: External pulleys linked up.

Usage Notes:

This roller is about as easy as it gets for making round stars. The size shown here can take a cup of cores and turn it into 15 lbs of stars within about 20 minutes, with a minimal amount of screening and futzing with the stars as they roll. The tire rotates at 30 RPM, which is pretty fast for a star roller of this size (larger size rolling containers usually need lower RPMs). The high speed combined with the ribbed surface texture help keep stars moving and separated when starting from small cores.

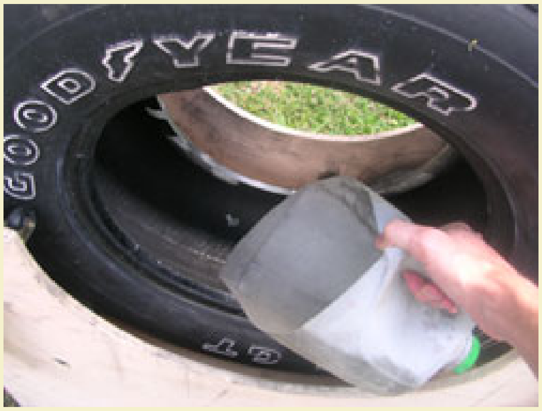

Figure 16: Home-made milk jug scoop for removing finished stars.

One advantage to the hollow center of the rolling container is that you can force a draft through the container such that all airborne dust is carried out away from the operator. A properly placed fan can virtually eliminate the need for a dust mask when using this roller.

The only disadvantage of a tire roller is the excess powder leakage that can happen due to powder being carried up the tire wall and released from the top, where it drifts down and often falls out along the sides of the tire. This can be minimized by not adding too much powder at once between wetting the stars. Even so, it is a good idea to line the shelf under the roller with paper so that the dust that does collect there can be easily removed.

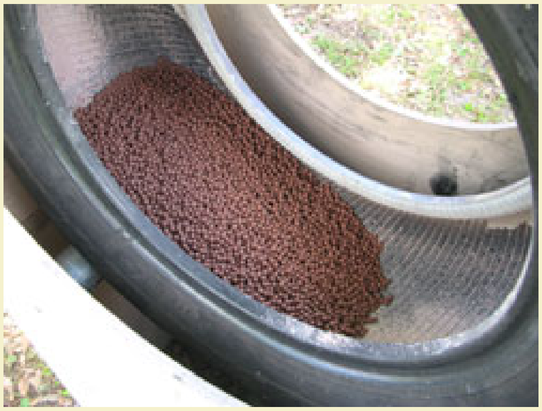

Figure 17: High volume and star uniformity achieved with the tire roller.

One question you might have had up to this point is "how do I remove the stars when they're done?" The simple answer to this problem is the large scoop made from a one gallon milk jug seen in Figure 17. With the roller running, simply insert the scoop and let the stars roll into it. Even a large batch of stars can be cleared out in only 3 or 4 scoop fulls.

Cleaning the roller is equally easy: simply yank out the tire, roll it over to your garden hose and spray it down. No bolts to unscrew and no water to bail out of a stationary container. Just spray the inside as you roll it across your yard, rock the water out of it (a rather tricky skill at first), towel dry the inside and slap it back on its cradle for the next batch!

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Beginner Project... **Page 1**

Color Changing Stick Wheel

by ***Michael Fales***

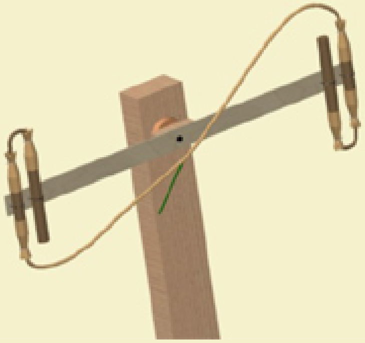


Figure 1: The completed wheel mounted on a 2x4 post.

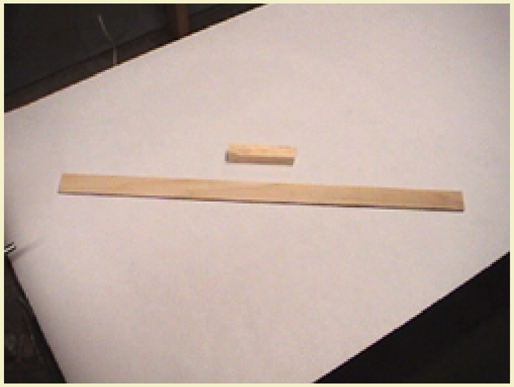


Figure 2: Wood pieces used to make the frame.

Materials:

- 1-1/4" wide by 24" long strip of thin plywood
- 3/4" x 3/4" by 4" long piece of pine
- 2" square or round of 3/4" thick pine
- 32" of 19 gauge steel wire
- 6 pieces of lightweight kraft paper 3" x 6"
- Approximately 46" of quickmatch
- Approximately 9" of blackmatch
- 2 3/4" ID x 4" long parallel wound tubes
- 2 1/2" ID x 6" long parallel wound tubes
- 4" length of safety fuse
- 1 3-1/2" long x 1/4" lag screw
- 2 3/4" #6 wood screws
- Cotton or linen string
- PVA or Wood Glue
- Mounting Board (10' long 2x4)
- Bentonite clay
- Tourbillion Formula
- Color Driver Formula

Introduction:

This wheel is easy to produce and will create a large spray of sparks and color that will awe even a jaded crowd. By transitioning from the color drivers to the tourbillion with titanium drivers (referred to as BP Titanium drivers through the rest of this article), the effect grows to a huge finish. It can also be used as soon as you finish it as there is no drying time or pasting required.

The Hardware:

The drivers are attached to a 24" flat stick of wood. Thin plywood works very well for this purpose because of its strength and resistance to warping. Thin strips of lumber will tend to warp or twist with the grain and will not provide adequate strength. Rip a 1-1/4" wide strip of the plywood and cut to 24" long. A small spacer is attached to the center of the stick to avoid collision with the mounting post while spinning. Cut a 4" long 3/4" by 3/4" piece of wood and clamp it to the center of the stick with a bead of wood glue between the two. Finish attaching the stick to the spacer with two 3/4" x #6 long screws inserted into 3/32" diameter predrilled holes to either side of center. The predrilled holes are necessary to keep the small pine spacer from splitting while inserting the screws. Drill a 9/32" hole through the center of the face of the stick and completely through the spacer. This will be the pivot point for the wheel. Cut a 2" square or disk of 3/4" thick wood and drill a 5/16" hole through the center (a plug from a hole saw will work just fine). This will become a large washer to reduce friction between the spinning wheel and mounting post.

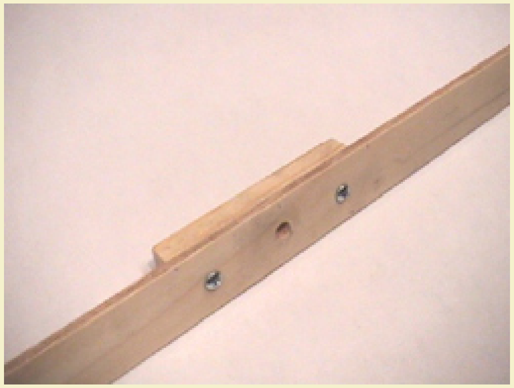


Figure 3: Reinforcing the hub with a block of wood.

The Drivers:
A total of four drivers will be used with this wheel however you can scale up or down as you want. The drivers are sequenced to fire on opposite ends of the stick at the same time and are measured carefully to create a simultaneous change in effect. Both of the following compositions contain titanium and pressing is required rather than ramming:

Black Powder Tourbillion Formula
(Ronald Lancaster)
Meal D 35
Potassium Nitrate 45
Charcoal AF 15
Sulfur 5
Total 100

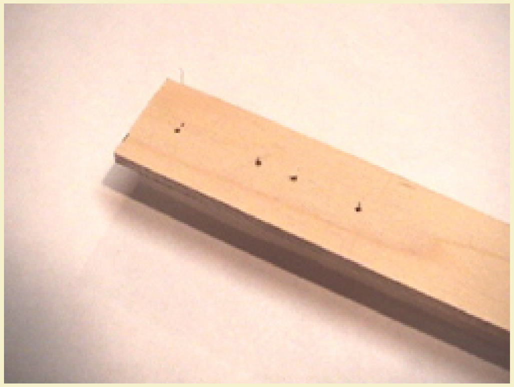
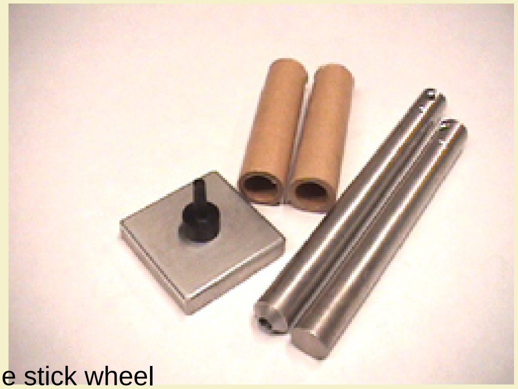


Figure 4: Drilling holes for tie-wires to pass through.

Personal notes regarding this composition: I use straight ball milled meal for the Meal D and I find that the particle size in the composition is so fine that it will act like a fluid while pressing or ramming. It can flow right out the top of your tube and in your face while pressing! Granulating the mix will take care of the dust problem, which involes adding about 20% water to the composition, pressing it through a window screen and allowing it to fully dry. The resulting particles hold together well enough to reduce dust by preventing them from blowing by the rammer, but are still weak enough to crush into a solid powder grain when pressing. Adding +10 titanium gives a great shower of white sparks; however you should PRESS rather than ram the composition once you add the metal to the mix!

Purple Driver Formula
(John Glasswick)
Red Gum 10
Parlon 20
Magnalium 20
Titanium 15
Strontium Nitrate 25
Cupric Oxide(black) 10
Potassium Perchlorate 25



These compositions burn with considerable heat and pressure which require a strong tube. The color drivers are created using Wolter Pyro Tool's 3/4" driver tooling shown in Figure 5. You can also use the simple home-made tooling as shown in Figure 7 with the BP titanium drivers and then drill out the nozzle hole by hand.

The color formula will provide a long burn time in just a 4" long tube. Place the tube over the spindle on the base and insert 1-1/2 teaspoons of clay. Press the clay nozzle hard using the hollow rammer. The nozzle will have to withstand pressure as well as erosion from burning titanium. Insert 1 teaspoon of color composition and continue to press using the hollow rammer until you clear the nozzle spindle. Switch to the solid rammer and continue pressing increments of color composition until you reach 3/4" from the top of the tube. Make sure to mark the tube where you stop so that you can fill both tubes to the same height. Fill the remaining cavity

Figure 5: 3/4" driver tool set with some strong driver tubes.

with loose clay and press solid (approximately 3/8" thick plug). Remove the driver from the tooling and repeat with the other 3/4" driver tube. Take both drivers outside and away from flammables. Drill, by hand, using a 1/4" bit into the solid clay plug just into the color composition on both drivers. These holes will be the passfire from the colored drivers to the BP titanium drivers.

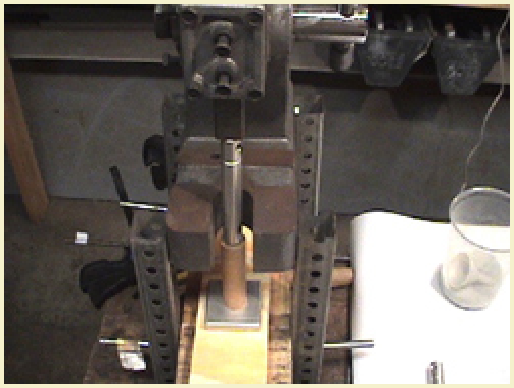


Figure 6: Pressing the color driver on an arbor press.

The BP titanium drivers are created using a home made set of tools which consist of a plywood base with a 1/2" diameter 1/4" tall nipple and a set of solid 1/2" diameter rammers. This formula burns fierce and fast so the tubes must be 6" or longer to produce a good burn time. At this length the 1/2" tube will need a reinforcement sleeve to keep from buckling or splitting under the pressure of pressing. Some use a split PVC sleeve in conjunction with pipe clamps. A piece of 3/4" copper pipe can also be used as a pressing sleeve. This particular Skylighter tube fits a little loose in this pipe so I wrap a few turns of 30 pound kraft before inserting snuggly into the tube. Place the tube on the base and insert 1 teaspoon of clay. Press the nozzle plug hard and solid just as with the color drivers. Insert 1/2 teaspoon of non-granulated or 3/4 teaspoon of granulated BP titanium composition and press solid. Continue to press the driver composition increments until you reach 5/8" from the top of the tube. Fill the remaining cavity with clay and press solid. It helps to switch to as short as rammer that is still practical while filling the tube. This will keep things vertical and reduce binding. Take both BP drivers outside and away from flammables. Drill, again by hand, using a 1/8" drill bit into the center of the nozzle plug end into the BP composition. Make sure to enter the composition about 1/4" to provide enough surface area to take fire as the wheel will be spinning.

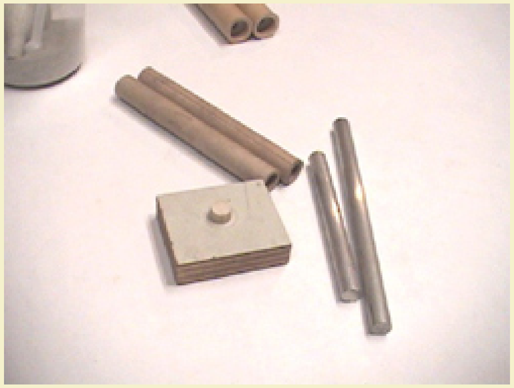


Figure 7: Home-made tooling for the 1/2" driver.

Mix up a small amount of slurry of NC lacquer and meal powder. Cut six 1-1/2" pieces of black match. Two of the pieces will fit into the smaller 1/8" diameter nozzle end of the BP drivers and four of the pieces will fit into the holes at both ends of the color drivers which are 1/4" in diameter. Prepare the drivers by inserting a few grains of fine grained black powder into the nozzles to help insure ignition. Dip one end of each piece of black match into the slurry and insert it into the drivers. Make sure that the blackmatch makes good contact with the black powder and composition behind the clay plugs. After the slurry is dried, nose the drivers with 6 pieces of light weight kraft paper cut to 3" x 6". Apply glue as shown in Figure 10. Wrap the glued paper around the last inch of each end of the colored drivers and the nozzle end of the BP titanium drivers.

Attaching the drivers:

The drivers on this wheel are placed so that it will change rotation upon color change. The rapid slow down and slight pause before reversing gives a nice effect of white titanium sparks. Measure in from each end of the stick and mark the center at 1/2", 1-1/2", 2" and 2-3/4". Drill through the stick using a 1/16" bit at each of the 8 marks. Cut 4 pieces of 19 gauge steel wire approximately 8" long. Center the colored driver within the first two holes on the end of the stick and make sure the nozzle is pointing the correct direction. Squirt a small amount of hot glue between the driver and the stick to hold the driver in place until the wire is attached. Place a BP titanium driver between the second set of holes with the nosing positioned next to the passfire end of the colored driver. Secure the driver with hot glue. Attach the other two drivers on the opposite end of the stick making sure to point the nozzles in the correct direction. Bend the wires into a "U" shape and insert each over a driver through the tiny holes previously drilled. Pull the wire underneath the stick and twist tightly with pliers to lock the driver in snug. Cut off the extra wire about 1/4" up from the stick.

Fusing the drivers:

Cut two 8" pieces of quickmatch and bare the last inch of each end. Insert one end of the quick match into the nosing paper of the BP titanium driver and the other end into the passfire nosing of the colored driver. Tie the nosing paper down onto the quickmatch and secure the quickmatch with a small dab of glue between the nosing paper and quickmatch paper. Cut a 30" piece of quickmatch and bare the last inch of each end. Insert each end into the nozzle end of each colored driver and tie the nosing paper down onto the quickmatch and secure with glue as before. Cut a small slit near the center of the long piece of quickmatch and insert a piece of safety fuse. Hold the fuse in place with a couple turns of masking tape.

Mounting the wheel:

Find a wide open space free from flammables. As seen in Figure 13, this wheel can spray titanium sparks up to 32 feet in diameter. Secure an 8 or 10 foot long 2x4 upright in the ground by burying securely. The 2x4 should be held firmly in place as the wheel will be spinning with great force. Pre-drill a 3/16" hole 2" down from top of the 2x4. Insert a 3-1/2" long by 1/4" lag screw through the center hole of the wheel followed by the wooden washer. Screw the lag screw into the predrilled hole on the 2x4 making sure to leave the wheel free to spin but tight enough to keep the wheel from wobbling back and forth. The lag screw may seem too long for what is needed, but shorter lag screws typically don't have a smooth shank behind the head that will allow the wheel to spin freely. Light the safety fuse, get back and enjoy. After the wheel has cooled you can clip the wires and remove drivers and the stick can be used again and again.

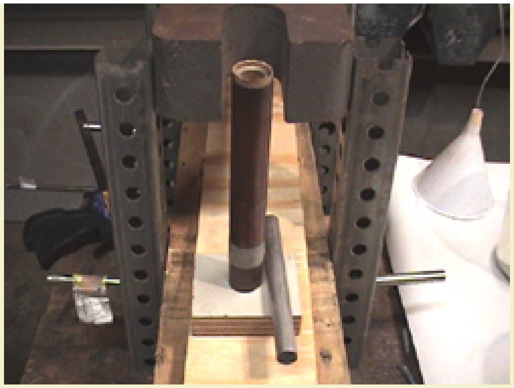


Figure 8: Pressing the 1/2" driver on an arbor press.

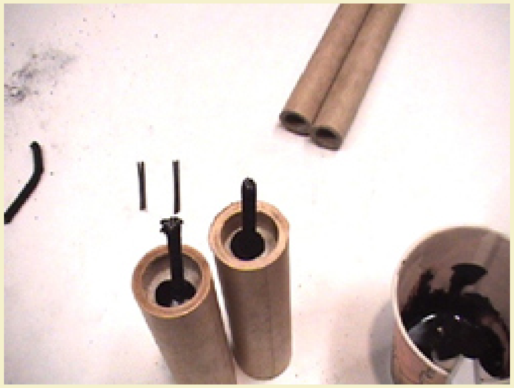


Figure 9: Fusing and priming the drivers.

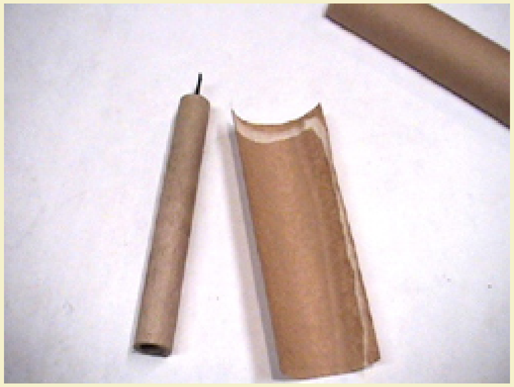


Figure 10: Applying the outer nosing paper.

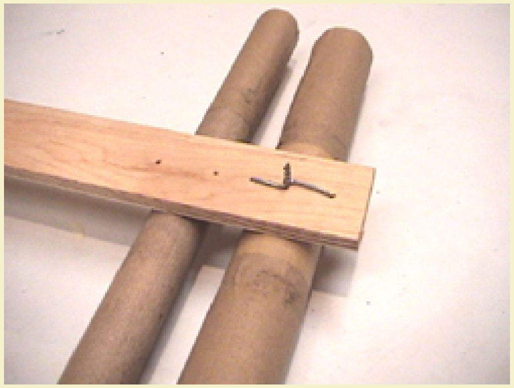


Figure 11: Securing the drivers in place with hot glue and wire.

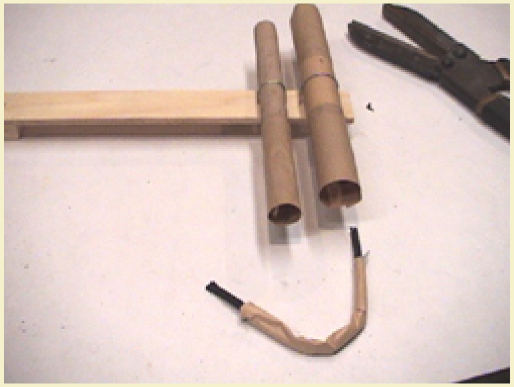


Figure 12: Fusing the drivers so the end of the 3/4" color driver ignites the 1/2" silver driver.

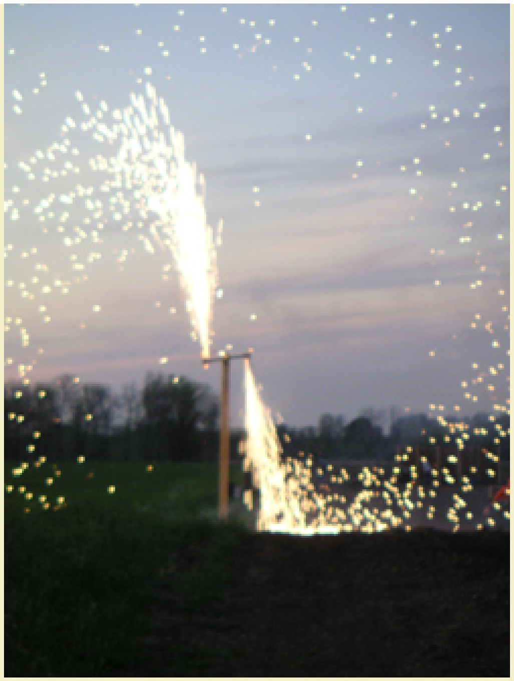


Figure 13: The silver stage of the wheel on display in a field.

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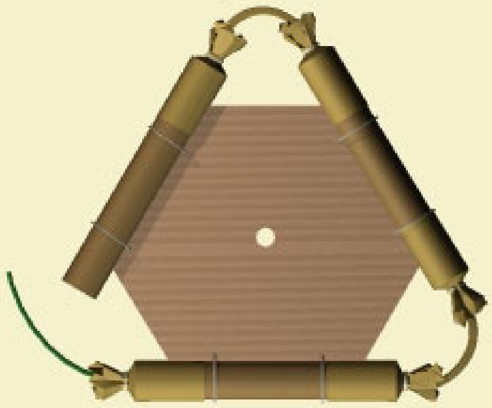
Volume 2, Issue 3

Build This...

Three Stage Triangle Wheel



March, 2002 Issue

Build This:
Three Stage Triangle Wheel.

Technique:
Round Stars, Part II.

Tool Tips:
Star Roller Comparisons

Autopsy:
German Made Class B Rocket.

Summary:
This wheel is one of those projects that fall under the "instant gratification" category, meaning you can crank one out and go fire it all within an hour (assuming you have the compositions already on hand). It makes for a perfect backyard celebration device, creating little noise but lots of effects. This is among the simplest types of wheels to make, and can easily be fitted with auxiliary effects such as whistles and color pots.

Formulas: 1/2" Gold Driver, 1/2" Firefly Driver, 1/2" KNO3 Silver Driver, 1/2" KClO4 Silver Driver,

Materials:

- (3) 5" long x 1/2" I.D. x 3/4" O.D. kraft tubes
- (1) scraps of 3/16" luan plywood at least 5" square
- (6) 5" long pieces of 18 gauge wire
- (5) 5" x 3" pieces of 30lb kraft (nosing paper)

Tools:

- 1/2" wooden or non-sparking metal rod
- Brass hammer
- Wire cutters
- Box nose pliers
- Drill Press
- 1/2" ramming base (spindle optional)

Unmeasured Materials:
fire clay (bentonite), meal powder, cotton or flax twine, white glue or wood glue, visco, black match

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Build This...

Page 2

Three Stage Triangle Wheel

Introduction:
This wheel project makes a good introduction to building revolving pieces, as it doesn't require the construction of any kind of fancy frame. Three drivers, often of a different effect each, are fastened to a triangular hub made of thin plywood, plastic or sturdy cardboard. I prefer the use of 3/16" luan plywood sold in 4x8 sheets at most home improvement centers.

Since some builders might not want to bother with cutting a full size piece of plywood into useable triangles, other materials such as lexan, acrylic or sheets of sturdy cardboard may be used. If scissors are your only cutting tool, you may be able to laminate several triangles cut from chipboard by stacking three or four of them with white glue between the layers. The finished material must be thick enough to hold the drivers on edge once they are wired onto the hub. Ideally you should be able to reuse your hubs many times over, so the more sturdy they are the better.

You can Print the Triangle Pattern with this link in order to have a template to trace onto your hub material.

Figures 1-3 shows the performance of each driver using the compositions given on page 1. When used with the ball-bearing type spin axis described at the end of this article, this wheel will spin quite fast, throwing sparks about 10 feet in all directions.

The basic design of this wheel can be enhanced easily with the addition of whistles and color pots. While whistles are strong enough to drive the wheel, they do not throw many sparks and can appear dull. It is best to fasten auxillary whistles to the sides of the main spark producing drivers, or use a whistle as the driver for an effect that produces attractive sparks but little driving force, such as glitter drivers.

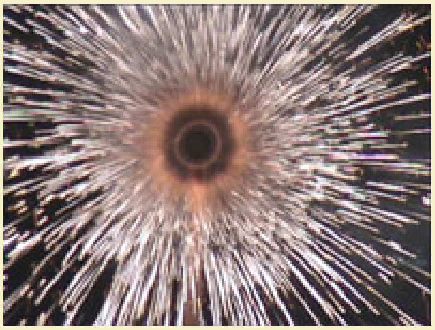
Figure 1: Stage 1: Ferro-titanium gold.

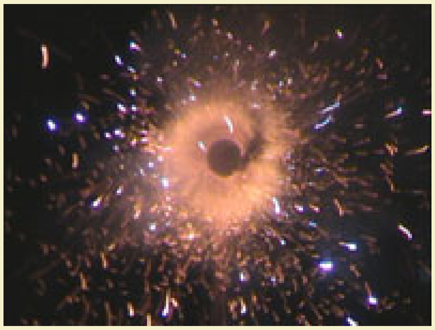
Figure 2: Stage 2: Firefly.

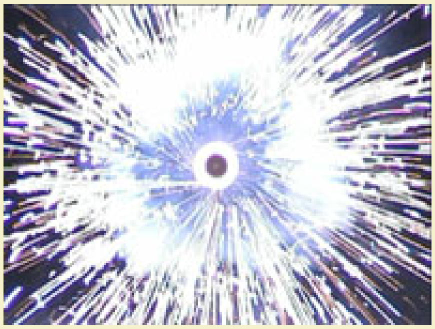
Figure 3: Stage 3: Silver flitter.

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Three Stage Triangle Wheel...

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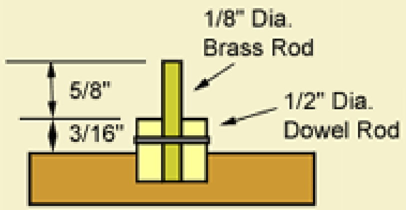

Figure 4: Home made wooden spindle.

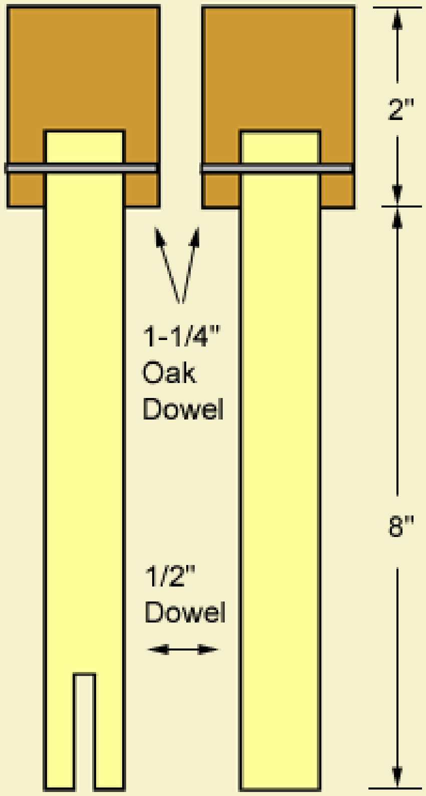

Figure 5: Drifts made from wood or aluminum rods with oak heads.

Making the Tooling:
The tooling required to make the drivers for this project can be made from parts available at most hardware stores. The spindle base can be a small 3/4" thick block of hardwood such as maple or oak. A 1/2" diameter hole is drilled half way into the base using a drill press to make sure it is straight. A 9/16" long segment of a 1/2" diameter wooden dowel rod is glued into the hole using wood glue and allowed to dry. Next a 1/8" hole is drilled into the exact center of the dowel rod, running all the way through it as shown in Figure 4. Into this hole a 1-3/16" segment of brass rod is inserted, which is held in place by a pin that runs through both the dowel rod and the brass rod. The pin can be a small nail or whatever is handy, as long as it doesn't exceed 3/32" in diameter.

Note that the brass pin is optional if the drivers will be vented using a drill press to make the hole. Using a drill also eliminates the need for the drift containing a hole in the end. In this case, you will only need to make one solid-end drift and a flat spindle with no brass pin. However, the drill method is slower, less accurate and requires caution. More on this method will be discussed later.

The drifts are made by cutting 9" long segments of 1/2" diameter wood or aluminum rods and capping them with 2" long segments of 1-1/4" oak dowel rods. The oak serves to provide more striking area when ramming, prevent damage to the ram rods and also provide a non-sparking surface so that a normal hammer may be used with them. The oak segments must be cut straight so that they will sit perpendicular to the drill stand when making the holes to receive the ram rods. The holes should be about 1" deep and centered as accurately as possible. A small nail is also used as a pin to hold the oak caps onto the rods, as seen in Figure 5.

If the ramming base is to have the brass pin, a 3/16" hole is drilled 1" deep into the bottom of one of the drifts. If wood is used to make the ram rods, they may be strengthened by dipping them in Minwax Wood Hardener for a few minutes and allowing them to dry. The inconsistent nature of dowel rod diameters may require some sanding before they will easily fit inside the tubes you will be using.

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Volume 3, Issue 8

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Build This...

1/2" I.D. Saxons

*by **"Big G"***

Summary:

Saxons are among the easiest spinning effects to create and will make an ideal project for those just getting started in pyrotechnics. These classic devices have been around since the early days of fireworks, and are surprisingly effective for their small size and simplicity. This article describes how to make several different saxon configurations that can be turned out in only 10 to 15 minutes!

November, 2003 Issue

Letter from the Editor:
Another Pyro Season

Build This:
Saxon

Technique:
Making Black Powder

Tool Tip:
Multi-Puck Powder Die

Gallery:
FPAGs Fall Festival

Class C Corner:
Great Willow, Spring Festival

Formulas: Gold 1, Gold 2, Silver,

Materials:

- Convolute Tube, 7 in. long, 1/2in. ID, 1/8 in. wall.
- Black Match
- Tissue Paper
- white glue
- powdered clay
- 30# kraft

Tools:

- 1/2" Spindle and Dowel
- Non sparking mallet
- Small brush
- Drill press or hand drill
- 5/32" drill bit

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Saxons

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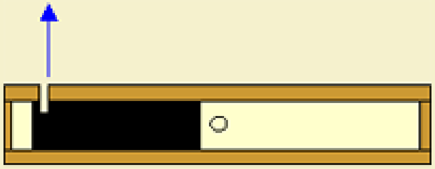

Figure 1: A single action saxon, driven from one end only.

Introduction:

Saxons are a very old fireworks piece that have been documented in many of the classical fireworks texts, including the works of Lancaster, Weingart and Kentish to name a few. In its simplest form, the saxon is a single driver that rotates around a pin driven through the center of the driver tube itself. A distinguishing feature of saxons is that they are driven from hole drilled in the side of the case instead of through the end. This results in a force perpendicular to the long axis of the case, allowing it to easily spin around a pivot point created anywhere along the length of the case (typically the center point). The simplicity of this design allows attractive pinwheel type devices to be easily made without the need for wooden or plastic hubs to hold the drivers. While not quite as impressive as a wheel, saxons can be assembled in 10-15 minutes, making them a quick fix when one hasn't "smelt the smoke" in a while.

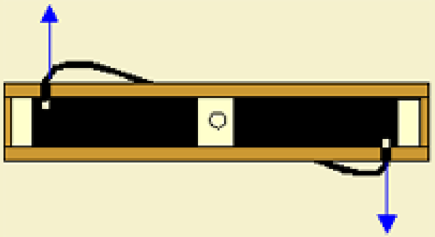

Figure 2: A double action saxon driven from both ends.

Saxons may be driven from one or both ends of the case, and color pots are often attached for enhanced effect. Saxon type devices are also commonly used as shell inserts, sometimes alternately called whirlwinds, creepers or tourbillions. When used as a shell insert there is no pivot point of course, so no hole is drilled through the case.

Figure 1 shows the simplest type of saxon, which is driven from only one end. In this illustration half of the case is charged with clay to act as an inert counter weight. It is actually possible to charge the entire case and then hammer a small nail right through the case and comp without effecting the performance of the saxon, although some may not be comfortable driving nails through live composition.

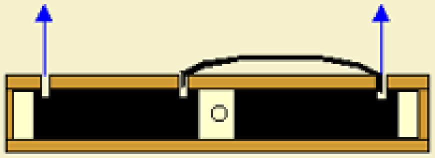

Figure 3: A reversing single action saxon. The end of the first stage ignites the opposing second stage.

Figure 2 shows a saxon that burns from both ends, resulting in more spark output and higher RPMs. The two opposing holes must be fused together with a piece of piped match so that they ignite simultaneously.

Figure 3 shows a reversing saxon, which is similar to a double saxon only the second exhaust hole is on the same side of the case as the first, and it doesn't take fire until the first driver is finished. A third hole at the end of the first drivers charge is used to pass fire to the second driver. The effect is a spinner that ramps up to speed, then starts slowing down, stops and finally begins picking up speed in the opposite direction.

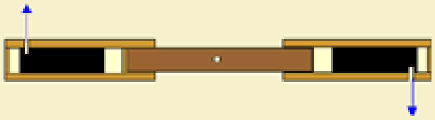

Figure 4: Larger saxons created by connecting single drivers to a center piece (usually a wood stick).

Figures 1-3 are simple saxons that are built from only a single casing. When a larger saxon is desired, it is more common to build the two drivers separately and connect them with a wooden center piece such as a dowel rod, as seen in Figure 4. Each driver is rammed such that there is a cavity above the end plug that is deep enough to slip snugly onto a dowel rod.

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Saxons

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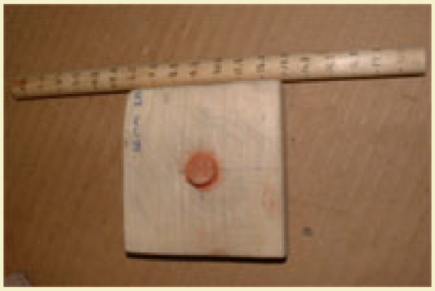
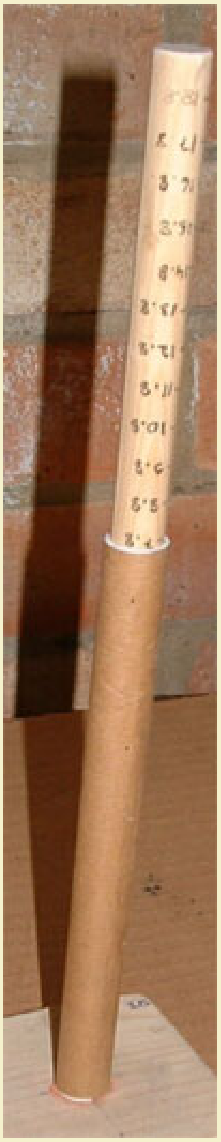


Figure 5: Rammer and Spindle. The depth marks are 1 cm (3/8 in.) apart..



Building a Single Saxon:
The simplest saxon is a single driver saxon. Half the case is charged with the driver composition, while the other half is filled with clay to act as a counter balance. The clay extends a little beyond the center point by about 1 cm (3/8 inch).

A simple set of tools can be made from a scrap of wood and a 1/2" dowel rod. First we make a half inch spindle by taking a 4x4 inch wood piece and drilling a hole in the middle of one of it faces half an inch deep. Then a short dowel, about an inch high is glued into the hole. Another piece of dowel, made from wood, brass or stainless steel is used as the rammer. The rammer is drawn with depth marks as seen in Figure 5. Note the centimeter marks on the dowel. When loading, these markings allow us to know how much composition was already placed inside the driver.

The driver being loaded in Figure 6 is half inch ID and 18 cm (7 in.) long. It was made by dry rolling a sheet of manila folder paper (or European 280gms paper) measuring 18cm x 20cm (7 in x 8 in.) around a 1/2 inch diameter rod. The last half inch was covered with white glue diluted with 50% water – and it was overlapped by a sheet of 30# kraft measuring 18cm x 10cm (7 in. x 4 in.). The rectangle was covered with diluted white glue except for the first few inches.

The tube is first loaded with a clay plug about 1/2" thick. Next the driver fuel is charged in small increments. Before loading the comp, it is best to drill the exhaust hole just above the clay plug first. This will relieve you from having to drill through live comp, and also allows you to pre-install the fuse and ram the comp down on top of it, thus locking it in place. The exhaust hole should be about 1/3 of the size of the driver ID. Thus our 1/2 inch ID driver should have a 1/6 inch hole, which translates to about 5/32" for standard bit sizes.

After drilling the hole, insert a piece of black match about half the length of the driver into the hole. The driver composition is now loaded in increments that compress to about 1/2" each until the tube is filled about 3/8" shy of the midpoint. Marking the midpoint on your ramming rod plus another mark 3/8" above and 3/8" below this point will help when ramming saxons.

The remainder of the case is now loaded solid with powdered clay, which acts as an inert counter weight so that the saxon will not have to work as hard to spin around the center point.

In order to secure the fuse against the casing and protect it from getting battered during storage, a few turns of tissue are wrapped around the end as seen in Figure 8. Some glue is brushed on the casing, being careful not to get any on the fuse or in the area where the fuse will come in contact with, then the tissue is wrapped around it. Keep in mind that this tissue will act as quick

Figure 6: - Saxon filled with clay up to the mid point. The depth mark shows 7.8 cm (3 in.) from top..

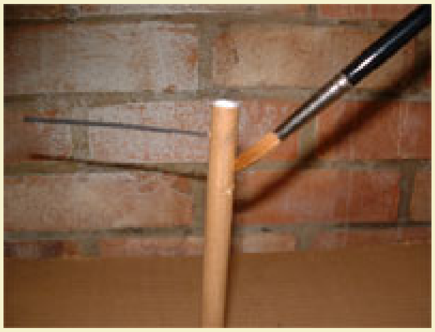


Figure 7: After loading and fusing the saxon, glue is applied around the fused end to secure the nosing paper.

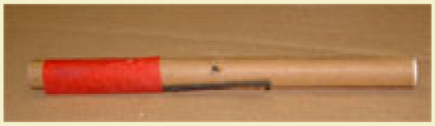


Figure 8: A completed single drive saxon. Note that the driver hole runs perpendicular to the spinning axis hole.

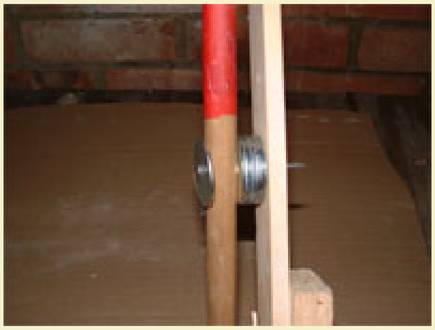


Figure 9: Washers used to space the saxon away from the launching stick, thus avoiding contact during operaion.

match as soon as the fuse burns up to it, so be sure there is enough bare match exposed to give you ample get-away time after ignition!

The last step is to drill the pivot hole at the center of the case. This needs to be drilled in the middle of the driver through both walls and clay, perpendicular to the driver hole. The diameters should be just slightly bigger then the pin you plan to mount the saxon on.

Firing the Saxon is similar to firing a wheel. It can be a simple matter of driving a nail through the Saxon hole and onto a wooden pole 2 meter high. However, such a method tends to be problematic as the Saxon hits the wood while rotating. The nail head can also dig into the tube and slow it down. An improved setup is shown in Figure 9. The driver sits between large zinc washers that prevent it from contacting both the wood and the nail head. The nail is not hammered in too deep, so the discs and Saxon sit loosely on the nail. The discs are smooth enough to create very little friction and allow the Saxon free movement.

Design Notes:
Unlike end burning drivers in which the exhaust hole is drilled into clay, the exhaust hole of a saxon is drilled into the driver’s wall. This means that fire eats through the paper and makes the hole larger and larger during the display. This causes the saxon to gradually slow down and, if the hole becomes too large, can ruin the effect of a continuous circle of fire.

There are a few ways to solve this problem. The first is to use a faster burning composition that does not burn hot or long enough to erode the hole much. The most common compositions for saxons are based on meal powder, which burns cooler and quicker than most color compositions involving barium nitrate or potassium perchlorate. When color saxons are desired, then a thicker walled tube must be used to accommodate the increased hole erosion.

Another alternative is to use a conical end plug such as the type used when making tourbillions. This requires a tapered rammer to make the plug, then drilling the exhaust hole such that it passes through the thin wall of protective clay left by the taper. When making double saxons with conical plugs, the drivers would have to be made separately and connected by a wooden dowel as shown in Figure 4.

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Saxons

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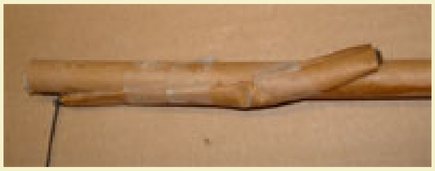

Figure 10: Fusing a double action saxon with piped match.

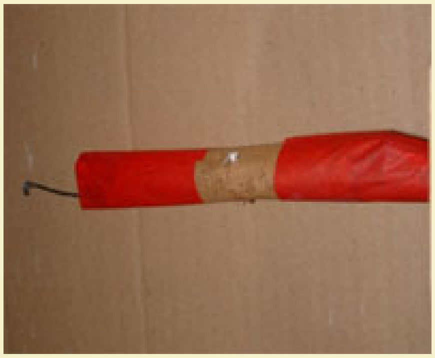

Figure 11: Finished double action saxon.

Double Saxons:
Double Saxon is still constructed using a single driver, except this time the entire driver is loaded with composition and the exhaust holes are bored at both ends. The tube will be mounted onto the spindle and loaded in the following order:

1) 3/8" of clay for end plug.
2) Composition up to the middle point minus 3/8".
3) 3/4" of clay.
4) Composition up to 1/2" from the top.
5) 3/8" of clay for end plug.

Double Saxons can be ignited using a “single stage” where both ends fire simultaneously (see Figure 2) or “two-stage” ignition where one side of the Saxon finish burning before the other end starts (see Figure 3).

Commercial outfits typically use two separate drivers that are pasted together to form the double Saxon (see Figure 4). This allows the manufacturer to utilize the same machines that load fountains and drivers to load saxons as well.

Building a Single Stage Double Saxon Begin building the saxon just as you would the single saxon described previously, except the black match used to fuse the hole needs to be long enough to reach the opposite end of the saxon. When the driver comp is rammed to 3/8" shy of the center point, only charge 3/4" of clay above it. Driver comp is then rammed above the central clay plug until within 1" of the top.

At this point you can drill the second vent hole 5/8" from the end of the tube, making sure that it points in the opposite direction as the first hole. While you could drill both holes before loading any composition, it can be hard to get the rammer past a pre-drilled hole, since it tends to cave in the tube wall slightly.

After drilling the second hole, ram more composition until the tube is filled level with the new hole. Now slip a piece of loose fitting quickmatch pipe over the blackmatch extending from the first exhaust hole, then insert the other end of the match into the second exhaust hole (see Figure 10). Ram another increment of driver comp so that the tube is filled to within 1/2" of the top, thus locking the black match in place. Finish by ramming the final 3/8" plug. Use tape to secure the connecting piped match to the driver so that it doesn't obstruct the area where the central pivot hole will be drilled.

Take another stick of black match and slide it into either end of the connecting piped match. This will be the ignition point for the saxon, and all it needs to do is ignite the piped match at some point (which will immediately ignite both ends of the saxon at once).

To give the Saxon that extra touch and good look – one can paste a Kraft #30, covered with 50/50 glue/water mix over the quick fuse casing and tube (but not over the exposed black match tips or the jet holes) and then use the same trick shown in the construction of single Saxons to cover and secure the fuses with tissue paper. Figure 11 shows the complete Saxon ready for storage and display.

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Building a Two Stage Double Saxon

Starting with the same procedure used to build a single stage Saxon, we repeat the steps up to and including the central clay plug. We now take the Saxon off its spindle and drill 2 holes. The first hole will be 3/8" above the plug and oriented to oppose the direction of the first exhaust hole. The second hole will be 5/8" from the top of the tube so that it is in line with the first hole. This second hole may be drilled later after the comp has been rammed close to the end so that you will not have to slide the rammer past the dimple made on the inside of the case when drilling the hole.

Now take the bottom fuse and place a segment of quick match pipe over it. Push the other end into the middle hole and consolidate an increment of composition onto it to hold it in place. Keep on filling the Saxon with composition until you are par level with the top hole. Insert another fuse to this hole and consolidate your last increment over it. Plug the top with some more clay.

To finish the Saxon off, use the pasted kraft paper or foil tape to hide the quick match and make sure you cover all of the fuses holes with tissue paper. Failure to protect the passfire match can result in premature ignition of the second stage.

Upon ignition of the fuse near the top of the Saxon, the composition will burn with one type of composition until it reaches the mid point of the Saxon. Then the second fuse will ignite, and as the fire from the first jet hole dies, the second jet hole will spring into life with a different effect altogether.

The ability to mix to different effect into one Saxon makes this the most lovely of Saxons. Try to filling both halves with different compositions for an attractive effect.

Design Notes:

Note that the reversing saxon shown in Figure 3 is a two stage double saxon built as described above, with the only difference being that all holes are drilled on the same side of the tube. This causes the second stage to spin in the opposite direction as the first stage.

It helps not to drill all the holes at the beginning before loading any composition. The reason is that drilling into the tube causes it to “cave in” and makes it hard to slide the rammer in and out easily. Also, some composition tends to escape out of the open holes. Therefore, I prefer to drill the holes as late as possible during assembly.

Saxons are easier to construct than related effects such as wheels, and they take only minutes to crank out if you have all the compositions on hand. However, the maximum number of effect you can put into a saxon is more limited than wheels or other complex rotating pieces. Saxons are driven by one or two jet holes at most. This means that there is a limit to how much power can be allocated for “pushing” the saxon and this limits the amount of external payloads that can be attached to them (such as color pots, whistles etc.). The fact that the exhaust hole widens with time means that the pushing pressure drops as burn time progresses, whereas this is not a problem with wheels driven by end burning drivers.

Saxons look best as a part of a larger effect. In Victorian times they were used in conjunction with large lance pieces to provide animated effects such as rotating wheels on chariots. Even today, igniting a few saxons together with large fountains in between is an impressive effect. In my house, they are still the most popular wheel around!

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Highlights from the 4F 2002 10th Anniversary Show

This year marked the 10th Anniversary of the Florida Pyrotechnic Arts Guild (FPAG), and guild members spent the entire year working on a completely hand made show to be fired for the annual Florida Fall Fireworks Festival (more commonly known as 4F).

Under the direction of Mitch Piatt, the current president, this show demonstrated that the hobbyist community can produce a show that is indistinguishable from commercial quality. In fact, the show contained many items that have disappeared from modern displays for many years now. Nearly every type of pyrotechnic item was employed, with a shell count of approximately 1000 shells, many of them multi-break canisters with inserts. All canister and ball shells were produced in the traditional manner with paper casings, and all multi-breaks employed spolettes. Hundreds of rockets, wheels, girandolas, gerbs, mines and comets provided variety that is sorely missed among typical commercial shows.

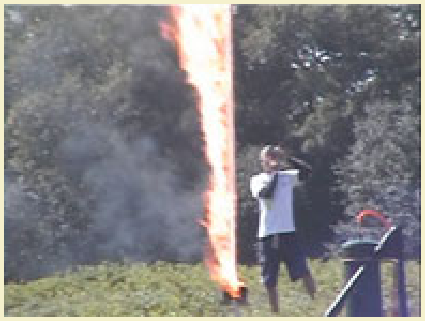
Perfect weather, a cloudless starry night and optimal wind direction made for a show not likely to be forgotten by those lucky enough to have been there.

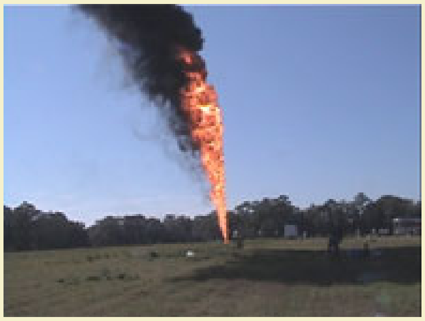
One of several rocket flights being assembled.

The Rocket Scientists assembling their contributions.

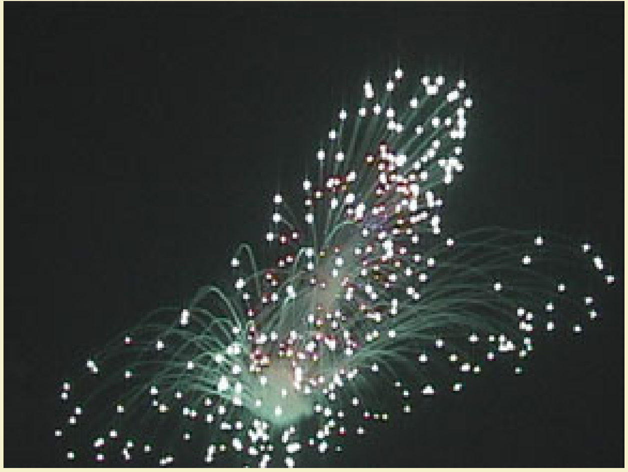
Over 100 6" paper ball shells being loaded into racks.

Murr Rhame demonstrating his flame projector.

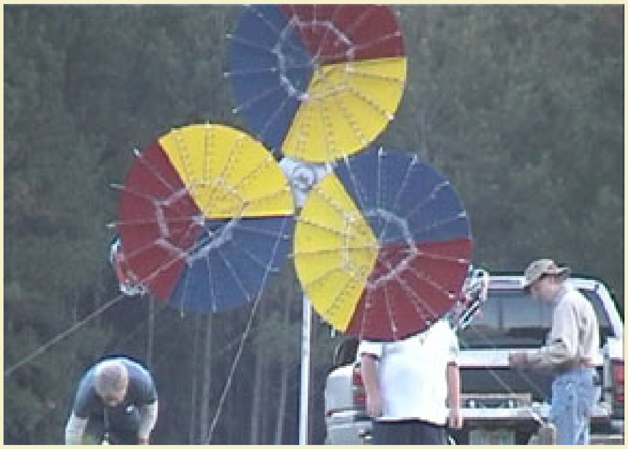

Compressed CO2 forces liquid kerosene through a nozzle, past a pilot flame and then almost 100 feet into the air.


Radiated heat can be felt several hundred feet away from the tall column of flames!

Loading an 8" Malta Shell made by Bennie Farrugia and Paul Schembri.



Break #2 of the 8" Malta shell during the show. The inner ring is burnt out, but the second and third rings can be seen.



John Webb and crew setting up the color wheel.

Color wheel in action.

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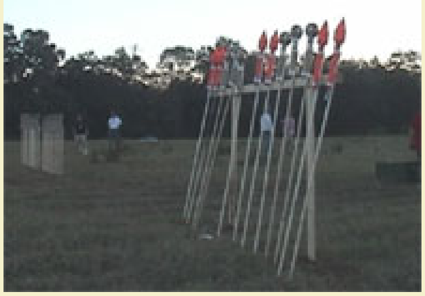
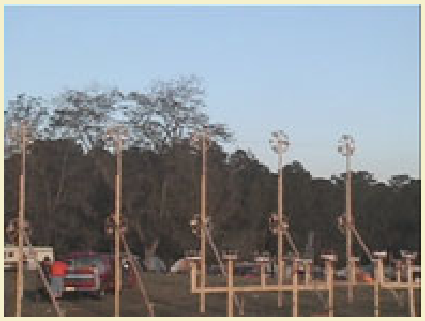


A dozen 6 pound rockets ready to fire.

A flight of three 6 pound rockets with 6" ball shell headings.

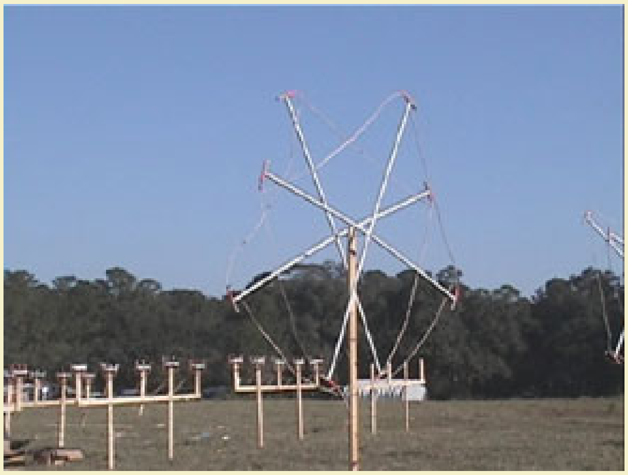
A flight of two 6 pound rockets with triple ring rising effects.

Anthony Jernigan setting up his wall of wheels.



A 20 foot high wall containing 10 wheels.

Glitter wheels in action!



Simple but large wheels made using PVC pipe.

PVC wheels in action.

A flight of three double petal ball shells.

One of several multi-shell go-getter segments.

One of many triple sets of 6" double petal ball shells.

Many elegant spider shells filled the sky during the show.

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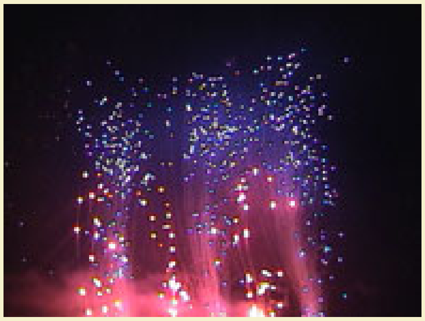
4" color changing mines.

Sequentially fired rainbow mines.

Six inch mines with color inserts and reports.

A three-fer of willow with blue inner petals.

More double petal six inchers.

Dave Goodfellow's excellent photo of Kyle's ring and comets shell.

Dixon's infamous screamer shells.

Nice purple (Buell's purple formula).

Mitch's kamuro sun and willow planets shells.

A flight of 10 bucket bottom girandolas.

Insert shell with bottom shot.

A wall of 20ft fountains.

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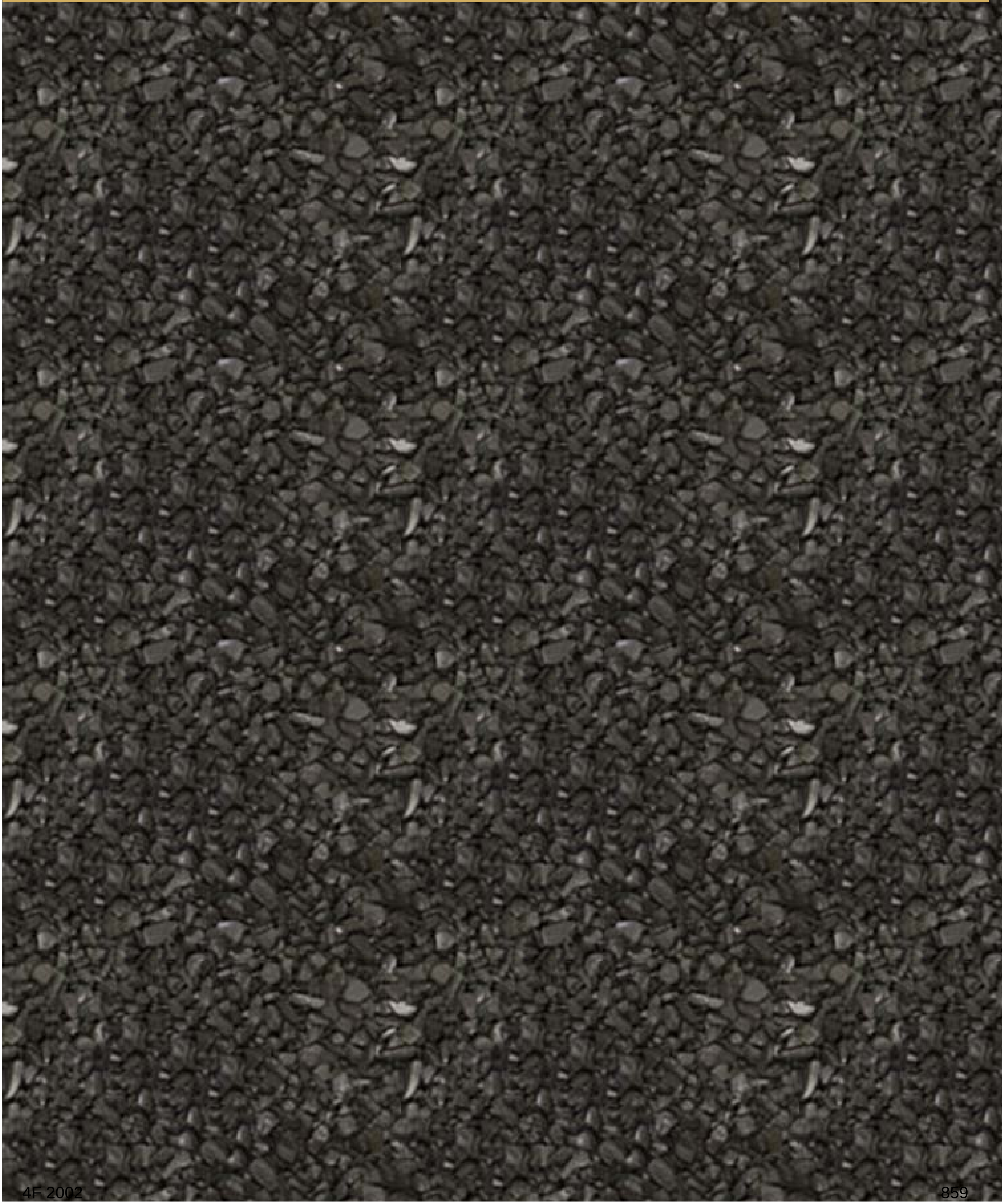

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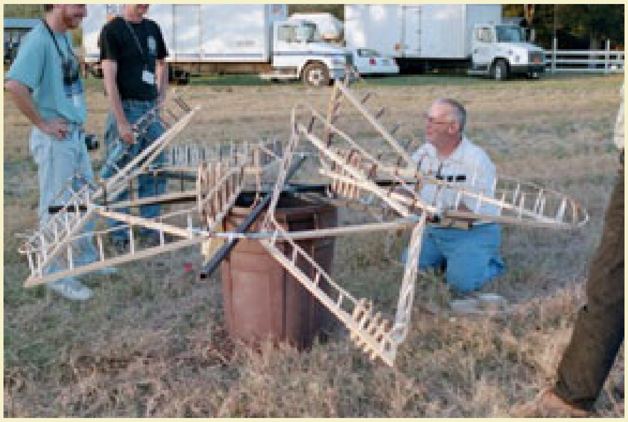
Gallery...

Florida Fall Fireworks Festival 2001

A flight of one thousand rockets fills the sky (and ground) with 4 inch breaks for several minutes.

Setting up some wheels for competition.



Assembling a maltese star fish setpiece for competition.

A hardy crew of tourbillion makers with their bounty of 100 large troubillions.

One hundred guild-made tourbillions taking flight.

A double petal from round shell competition.

A sun and planets from canister shell competition.

An array of gerbs from ground level competition.

A scene from Santories splendid show on Saturday night.

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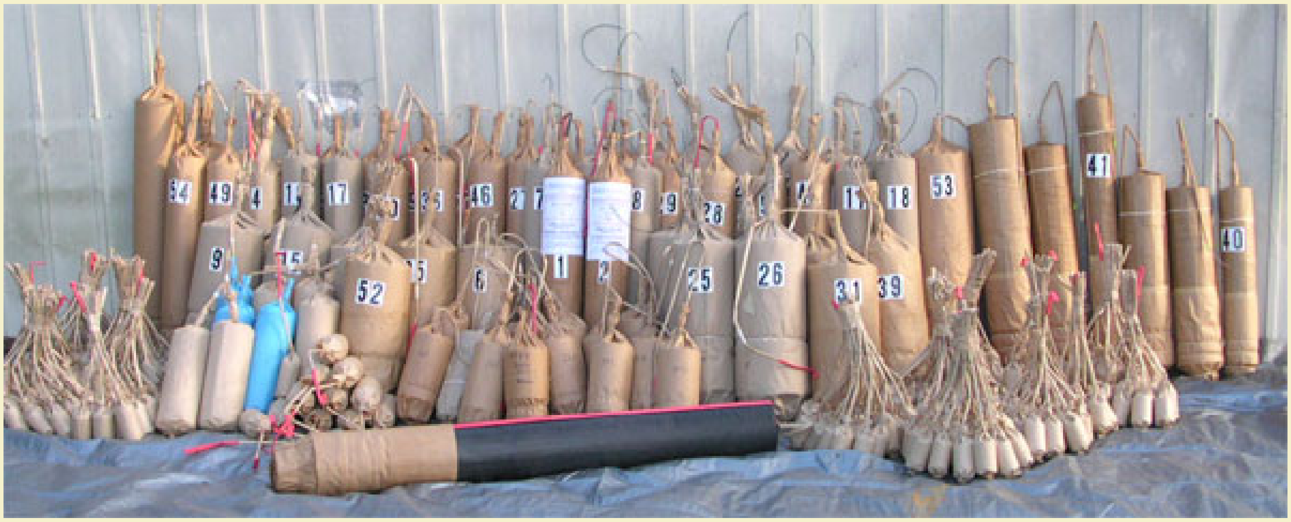
FPAG's 2004 Maltese Show



In the Fall of 2003, under the direction of club president Mitch Piatt, the Florida Pyrotechnics Arts Guild (FPAG) took on a project that was the first of its kind in America: the construction of a fireworks show using only authentic Maltese techniques. Several thousand dollars were allocated to the project, along with generous donations from PyroSupplies.com, Greg Dixon and Skylighter to help with the large amount of materials the large, chemical-hungry multi-break shells would consume.

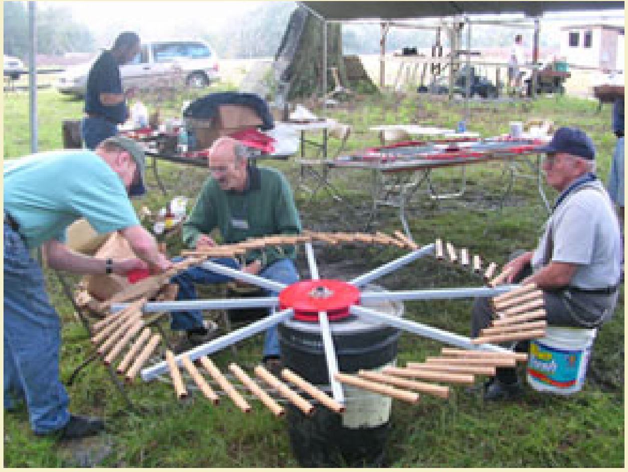
Over the course of the year, despite setbacks caused by an onslaught of hurricanes and a relatively small group of core members to keep the project going, over 60 large shells were produced along with 300 small finale shells, a large counter rotating wheel, a handful of lampare shells and two lance pieces.

The statistics were quite impressive for a non-commercial effort by only a dozen or so pyro hobbyists. 700 pounds of chlorate star composition was consumed, along with 100 pounds of flash and 500 pounds of black powder. Using a hydraulic press and guild-built star plates to produce 5/8", 3/4" and 7/8" pumped stars, a grand total of over 20,000 stars were pumped out over a 3 day period! Over twelve hundred 1-1/4" insert shells were produced for use in 10" snail shells and other large ring effects. Three hundred 3" shells were produced in just one week for the finale, 30 of them containing a total of 360 hand rolled 1/2 inch colored "beraq" salutes.

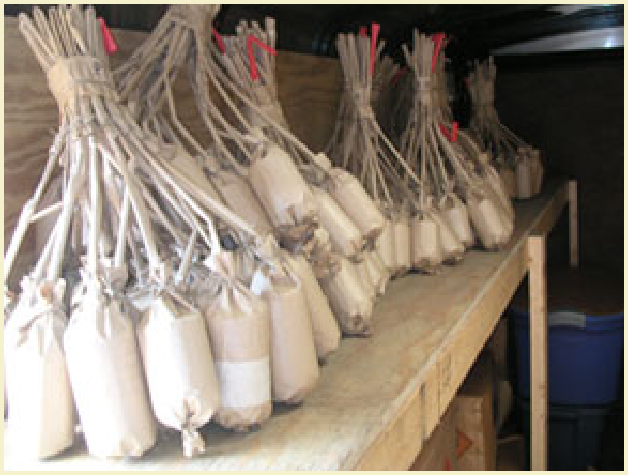
The effort was not limited to only those members working together in Florida either. Kolin Kimbrough of Texas brought six large shells of his own, one of them a perfectly performing 6 break 5" with bottom shot. Renowned shell builder Don Rowe also brought a 7 break 8" that weighed 90 pounds and stood about five feet tall (the black shell shown above).

When the work was all done and the fruits of everyone's labor were placed on a tarp for one final look on the day of the show, the sight was awe inspiring. What was once the realm of websites and photographs taken in Malta was now spread out before us for the first time ever on American soil!

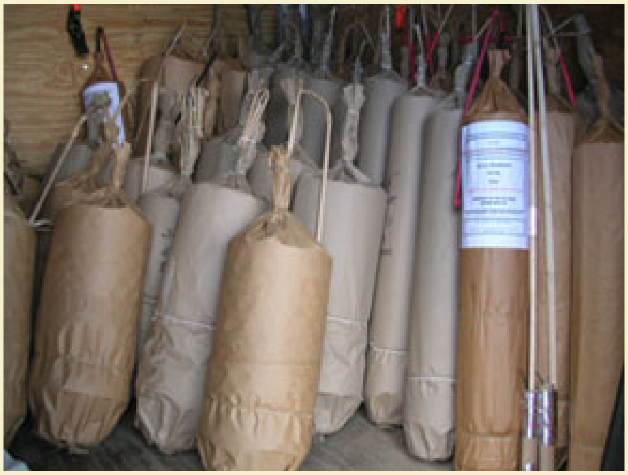
Some of the builders responsible for this show pose next to their work. Paul Schembri from Malta can be seen front and center, sitting to the right of guild president Mitch Piatt.



Paul Schembri works with other guild members on the large counter-rotating wheel.



Bundles of 3 inch "kaxxa" finale shells, pronounced "ka-sha".



Large shells fill the magazine, with 10" shell-of-shells in the forefront.

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FPAG Maltese Show...

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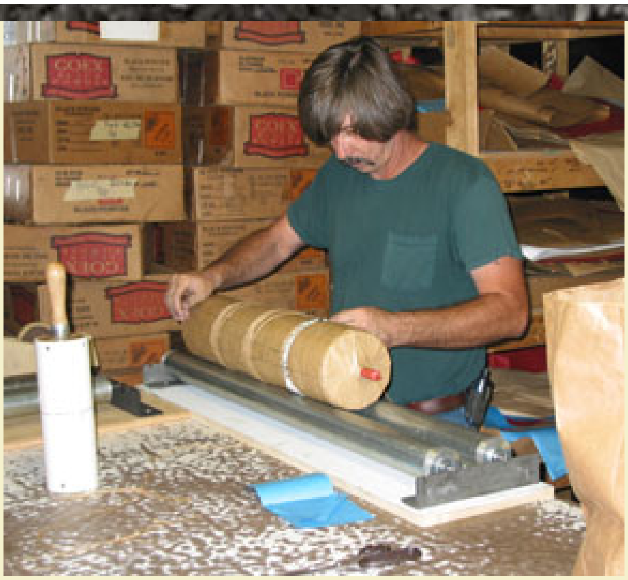
A box of 3/4" stars pumped 70 at a time using a hydraulic press.

Trays of rough powder drying in the sun.

Multi-break cans with outer star rings loaded.

Containers filled with bottom shot shells.

Dan and Joe assembling breaks together.


Mitch stringing breaks together on his home-made Maltese roller.

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FPAG Maltese Show...

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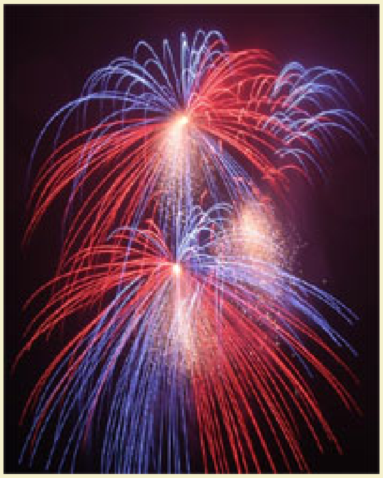
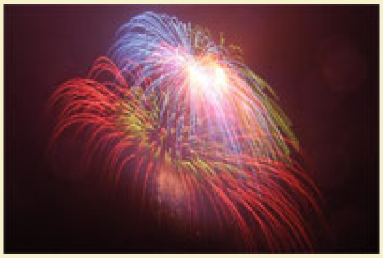


Video Clip

6" Single Ring w/Pistil

Av. Weight: 20 pounds
Lift: 230 grams

Description:
This style of shell, along with the 7" size, is the "workhorse" of Maltese displays, usually configured with three breaks and a bottom shot. Each break has six rings of nineteen 3/4" pumped stars and an inner pistil of contrasting 1/4" round stars. Typical designs for the outer ring include solid color, half and half, quadrants (see left photo) and glitter. The bottom shot is sometimes substituted with a silver spider shell.

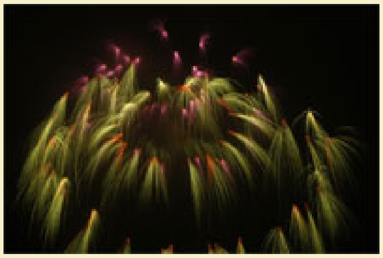


Video Clip

7" Double Rings w/Pistil

Av. Weight: 32 pounds
Lift: 430 grams

Description:
The 7" size adds enough extra space to insert an additional ring of 5/8" comets inside the outer ring of 3/4" comets. This produces an attractive triple layer effect with an inner "doughnut" of stars inside the outer ring, along with the central cluster of 1/4" stars. Since the 1/4" stars burn out rather rapidly, they can be hard to spot in the videos.



Video Clip

10" Triple Insert Rings

Av. Weight: 20 pounds
Lift: 800 grams

Description:
This is a 10" single break shell with no bottom shot, and includes ninety 1-1/4" color insert shells. The inserts are made with 1/4" color stars and are rolled and spiked just like a tiny Italian style canister. They are fused from the side using regular Chinese time fuse, with three separate timings to produce three rings. Five rings are stacked inside the shell, with 18 shells in each ring. The first row of 18 shells represents the first timed ring. The second and third rows combine to create the third timed ring, while the forth and fifth rows produce the second timed ring. The reason the second ring is placed at the bottom of the shell is to produce a jumping back and forth effect of the rings rather than a predictable progression.

Video Clip

10" Snail Shell (Bebbux)

Av. Weight: 20 pounds
Lift: 800 grams

Description:
This is another 10" single break insert shell with no bottom shot. Four rows of eighteen 1-1/4" insert shells are produced with 1/20th of a second timing increments, then carefully arranged in order of time so that the inserts break in a clockwise or counter clockwise progression (direction depends on break orientation of shell). The inserts are typically grouped so that groups of four will break at the same time, rather than each one having a slightly different timing. The end result is a circular progression of tiny shell breaks working their way around as they expand out, creating a spiral pattern and thus the "snail" nickname.

Video Clip

7" Report Rings w/Pistil (Beraq)

Av. Weight: 30 pounds
Lift: 430 grams

Description:
This is similar to the 6" multi-break except the rings of 3/4" comets are replaced by rings of tiny salutes known as "beraq." This is one of the more difficult shells to build well due to the precision timing required on so many small salutes, and the sheer number of them that must be made to perform consistently. A well made beraq shell should produce distinct rings of salutes where the timing is so close that a single loud ripping sound is produced. Many different versions of beraq shells with various timed rings and colored report effects are fired during daylight hours at Maltese festivals.

Photography Credits
*Production Photos:*Jason Land & Kyle Kepley
*Shell Photos:*Tracey Baker
*Video:*Kyle Kepley

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Volume 3, Issue 4

Gallery...

Page 1

The Lily Fireworks Factory at Mqabba, Malta

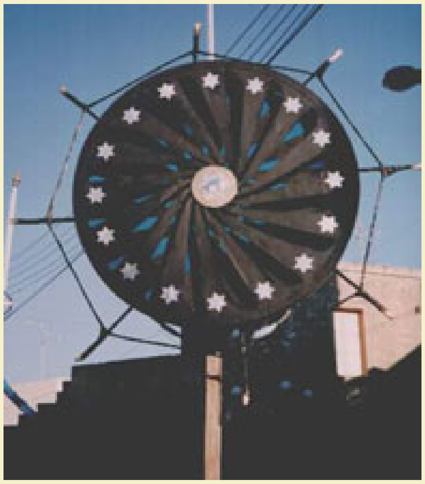
Lady of Lilies

The following photo gallery was submitted by Keith Dingli, a member of the Lily Fireworks Factory in Mqabba, Malta. All the fireworks shown in the pictures were produced by the Lily factory, which has a reputation for innovation and attracts many local and foreign visitors to its yearly festival in honor of their patroness Lady of the Lilies.

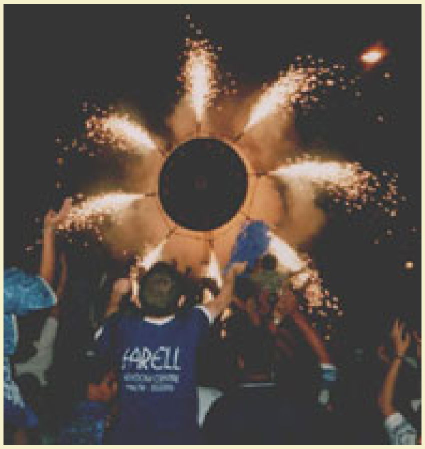
The Lily Fireworks Factory has been in operation since the 19th century and has since established itself as one of Malta's leading fireworks producers, both in aerial shells and ground displays.

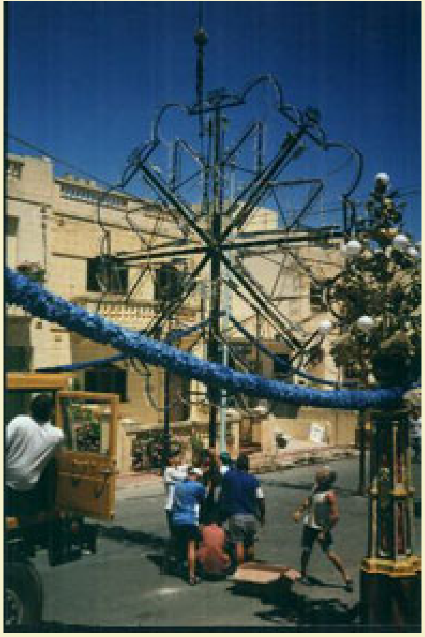
For more information about the Lily factory you can visit their well designed website at http://www.talgilju.com.

NOTE: Clicking on any picture in this gallery will open up a popup viewer that lets you view each picture in a larger size.

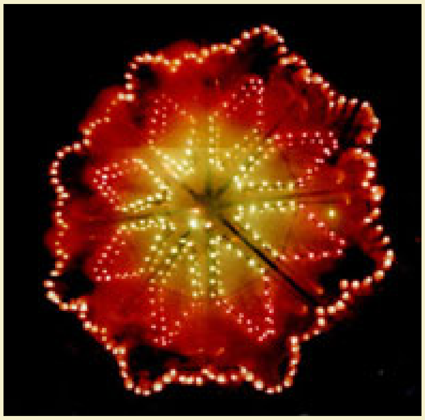

A wheel from Lily's year 2000 festival.

Young pyrotechnicians posing with part of the wheel.

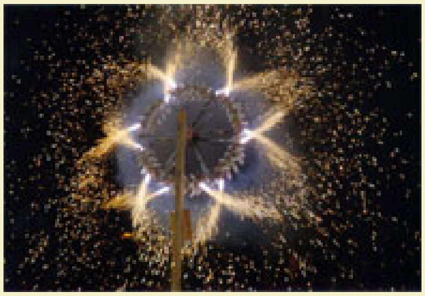

The wheel comes to life during the festivities.



Setting up one of the large animated set pieces generally known as "irdieden". The large wooden frames are dropped into permanent holes in the pavement specifically created for this purpose!

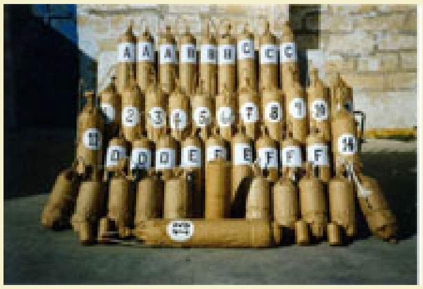


Even in a still photograph the wheels are stunning. Now imagine the inner petals rotating so that the inner and outer colors rotate between red and yellow!



Funtana blu, two counter rotating wheels with blue color drivers.

Like most hobbyists who like to create photographic records of their work before it is gone forever, the Maltese often stage photographs with their pre-festival inventory.



The main body of a Maltese show usually consists of large diameter multibreaks. Clusters of smaller single break shells are only used in the finale.

A proud Lily worker posing with a years worth of his club's work for the 1999 festival.

More...

Mail Passfire.com

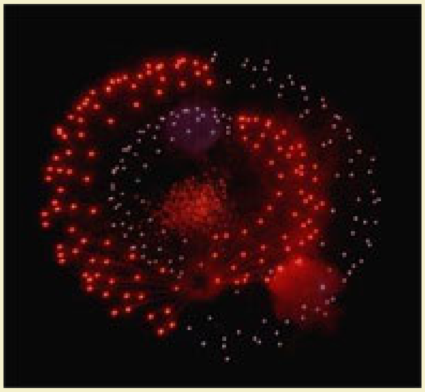
Lily Fireworks Factory...

Page 2

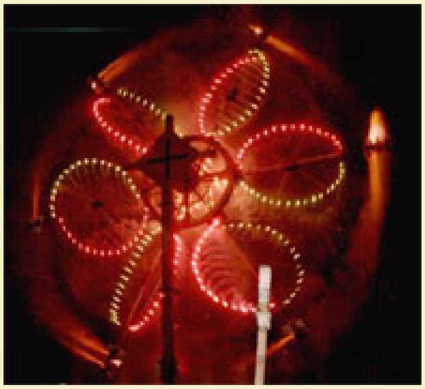
A dense burst of glitter comets.

An awesome photo of a double ring with alternating color on the outer ring. Center pistil stars have burnt out at this point.

Amazingly symmetrical double ring with center pistil. The remains of the previous break can still be seen.


A half and half shell, Maltese style!

A festive crowd participates in the band march on the day after the display. Keith can be seen holding a picture of the wheel.


This clear photograph reveals some of the mechanics behind an intricate rotating set piece.

Many multi-breaks drying in the sun at the Lily fireworks factory.

Keith Dingli posing with some of his clubs shells. Many thanks to Keith for sharing this collection of excellent photos with us!

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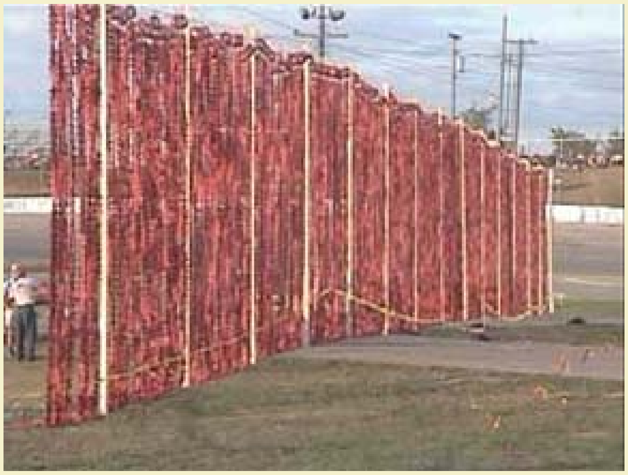
Gallery...

Highlights from PGI 2001



Superstring. The name says it all.

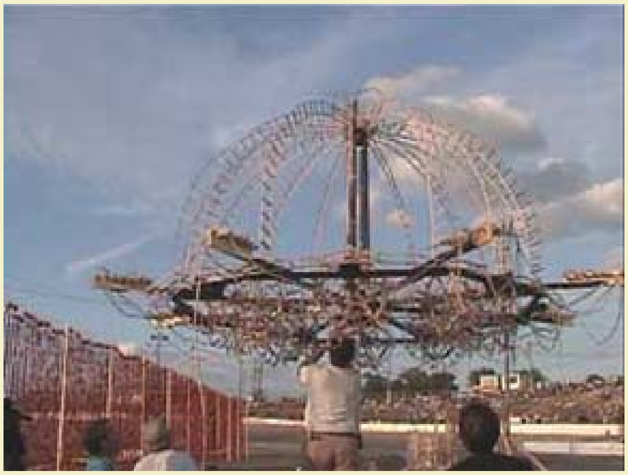
The Superstring in action!

Bill Swint working on his flight of 100 tourbillions for the closing show.

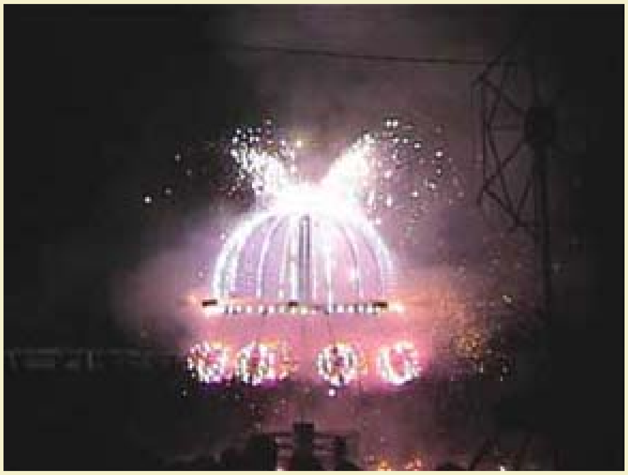
The tourbillions taking flight after the superstring.

Two perfect ring shells open during one of many shows.

A proud girandola builder waits for the competition to start.



An elaborate set piece crafted with uncompromising skill.



The "crown" setpiece lives its short life of splendor.

A perfect shell of shells opens during competition.

The 12 inch "big one" covers the sky, winning the Hoyt prize reserved for truely outstanding shells.

The megastring explodes in a fireball of glory!

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PYROTECHNIC RESOURCES

Links

This is a collection of links to all things pyrotechnical on the internet. If there are any sites that you like and they are not listed here, you can help make this list more complete by adding a link yourself.

Catagories:

Display Companies

15th August - Malta

Spectacular aerial and ground fireworks integrated with music

1st Galaxy Fireworks

1st Galaxy Fireworks are a UK based firework importer, wholesaler and retailer, supplying quality fireworks to buy online at wholesale prices. Our professional fireworks display team are also available to design and organise corporate and wedding fireworks displays.

Bartolotta Fireworks Co. Inc.

No matter how big or small we do it all

Elite Pyrotechnics, LLC

Idaho-based fireworks and pyrotechnics display services company. Providing outdoor aerial fireworks displays for any event in Idaho and Pacific Northwest region.

Lonestar Fireworks Productions

We have been providing quality Fireworks Shows in Texas for over a combined 10 years. Our customers receive the highest quality products with a commitment to artistry and entertainment value.

Nightlighter Fireworks Inc - Fireworks Display Specialist!

"Unique CUSTOM Fireworks Displays"

peter zuck - webmaster

is display company and links site. is a free site

Royal Design Firworks, Int.

Exclusiv Fireworks Entertainment Company. Digital fired show choreography concepts. State of the art products and systems.

Vulcan Fireworks

A European display company, not to be confused with the Chinese manufacturing company of the same name.

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Links

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Catagories:

How-To Info

A Complete System of Pyrotechny

Endless Amusement

Amateur Pyrotechnics & Chemistry Forum

Participate in in-depth pyrotechnical discussion on various topics. Over 500 members and growing everyday!

Andy K's PFP

Another hosting of the popular PFP

Building plastic ball shells

A good article on assembling plastic ball shells.

Carbon Cloth Anodes

For those into making thier own chemicals via electrolysis, this article shows how to make a carbon cloth anode.

Chemixtry Startpage

Startpage to other very good pyro pages.

Chinese Manufacturing Pictures

This is the best collection of pictures I've ever seen that show the construction of fireworks in China. The text is in German, but the photos are very educational.

How to Make Sugar Rockets

Detailed page dedicated to the process of making sugar-nitrate rockets.

International Fireworks Information Web

Everything about fireworks in China, and the world.

Jackery's Pyro

Formulary, Howtos (tools and finished devices), video footage, and much more.

Making Golf Ball Shells

How to make a small round shell using a golf ball as the case former.

Matt's pyro site
some simple how to info

Maxpowa
A Belgium site with some well illustrated how-to articles, links, formulas and other goodies.

Metal Grinding Machine
This useful article shows how to build a machine for grinding your own metals, then gives a few applications and formulas for using the ground filings.

Pyro Projects
Index of chemical experiments, including some pyrotechnic devices.

pyroheaven

Pyroworx
Nice page with lots of how to info on fireworks and firing systems

Raytech Animation Inc.
A web page dedicated to sharing knowledges of the fireworks industry on a global scale.

Spanish Manufacturing
This is the site of a commercial manufacturer in Spain, but it has good video footage of how they make fireworks. Click the Production link to access the video area. The Video 1 section shows a good sequence for loading a ball shell.

X-match
Canadian fireworks pictures, description for making an alternative to quickmatch called X-match.

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PYROTECHNIC RESOURCES

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Links

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Catagories:

Legal & Safety Info

BATF Explosive Materials List

BATF home page

DOT HazMat Transportation

Hazardous Materials Transportation Guides

Fireworks Injury Statistics

A nice article from the Pyrouniverse site, which summarizes some injury statistics and has some useful links.

National Council on Fireworks Safety

National Council on Fireworks Safety
4808 Moorland Lane
Suite 109
Bethesda, MD 20814 USA
Phone: (301) 907-7998

National Fireworks Association

Kind of like the NRA of the fireworks world. Membership in this group helps defend fireworks issues by funding lobbying efforts.

NFPA Home Page

OSHA Fireworks Manufacturer: Compliance Policy

CPL 2.73

U.S. Code, Title 18, Chapter 39

EXPLOSIVES AND OTHER DANGEROUS ARTICLES

U.S. Code, Title 18, Chapter 40

IMPORTATION, MANUFACTURE, DISTRIBUTION AND STORAGE OF EXPLOSIVE MATERIALS

U.S. Consumer Product Safety Commission

yet another example of Americans trading freedom for 'safety'

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Catagories:

Manufacturers

Fireworks

Celebrate all occasions with Coronations collections of fireworks and sparklers.

Arya Fireworks

Manufacturer of Panda Brand commercial fireworks.

Bingshan fireworks

firework manufacturer, exporter

Black Cat Fireworks

Retail fireworks with very nice page design

Blossom Fireworks Company

Blossom fireworks Company(www.bsfireworks.com) is a professional fireworks exporter in China. We have been exporting fireworks to all over the world for more than ten years. We manufacture fireworks according to our customers' requirements. We sincerely hope that we will have chance to offer you our best service! Welcome to visit our website at www.bsfireworks.com for more information about us. Blossom Fireworks Company Tel/Fax:86-731-5147099 Email: sales@bsfireworks.com www.bsfireworks.com

Delcor Industries Inc.

Full line of manually-activated electronically supervised firing systems

Dominator Fireworks

Dominator Brand Consumer Fireworks are the closest you can get to professional grade pyrotechnics. The graphics are all USA designed and printed with the highest quality inks and paper. The graphics will catch your customers eye, and the professional level performance will keep them coming back for more. Dominator Fireworks are available wholesale through our dealer network or by the container, direct from China. Our price to quality ratio is unmatched in the industry. Contact us for more info at mailbox@dominatorfireworks.com.

Firelinx Wireless Firing System

Next generation system with Reliable Wireless (pat pend) technology. Wired, wireless, manual, auto, all together at last, at an affordable price.

Golden Fireworks Co. Ltd., Liuyang, China

This is a wonderful fireworks corporation in China. Their products have nice quality and in a very competitive price.Very reliable

Lidu Fireworks

Website for Lidu fireworks manufacturing company in China.

liuyang flyingdragon fireworks Co.,ltd

China Liuyang flyingdragon Fireworks Co., Ltd is one of the largest producers and exporters of 1.3G Class B fireworks with 3 share holding fireworks factories . we mainly produce professional fireworks: Display shells :from 1.75¡å to 20¡å, with patent products with especial effect such as red carpet, green carpet, ballet on water and display UFO. Display cakes : from 0.5¡å to 4¡å, Roman candles: from 1.2¡å to 4¡å). Stage fireworks The products have gained ISO9001:2000 certificate and the quality is applied to the European Standard, AFSL and CPSC in the demand of our customers. We are exporting to more than 20 countries, such as USA, Germany, Holland, England, Italy, and Thailand, etc. With annual sales close to 200,000 cartons, our products have established good reputation at home and abroad as a result of the safety, stability of our products. With professional technicians and a skilled displaying team with advanced equipments, we have combined the traditional crafts with modern scientific technology in renewing our products in order to meet the needs of the market. we regard prestige and quality as the first of all . With more than ten years experience in the production and sale of fireworks , we are confident that products will give the fireworks company all over the world full satisfaction. we very much look forward to hearing from you. please visit our website :www.lxfireworks.com www.lxfireworks.com

Progress Professional Pyro

Progress Professional Pyrotechnics are China’s highest quality professional level pyrotechnics. Featuring a one of kind line of Low Level 1.4G Comets, Mines, Shells and Racks that Close Prox performance at China prices. In addition, Progress Pyro carries a full line of 1.3G shells, electric match and supplies. Please visit our website for complete purchase information or contact us at mailbox@progresspyro.com.

Saint Sebastian Fireworks Factory

A site for a Maltese manufacturing company. All text is in Maltese.

Union Band Malta, St.Andrew's Fireworks Factory, Luqa, Malta.

One of Malta's leading fireworks Factories. Especially known for its unqiue daylight shows amongst many other things. Produces both Daylight and Night time fireworks, Ground (chaterine wheels) and Air Fireworks.

Vulcan Fireworks

A site for the well known Chinese manufacturing company, complete with shopping cart and prices.

Wholesale Fireworks

Apollo Firworks are one of the best distribuors for class C product.

Mail Passfire.com

Links

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Catagories:

Personal Pyro Pages

Alan's Pyro Page

Documentation, photos and videos of many pyro experiments.

Andyboys

A few tutorials and movies.

Archived Jackie Whedbee

Lost but not gone forever

Brian's Pyro Page

Some of my projects and tools along with pictures from various celebrations.

Dan Williams Pyro Page

Good tool projects and nice pictures.

Dexter's Pyro Page

some nice how-to illustrations

Dimock's Pyro Page

One of the oldest and most well known personal pyro pages around. Tons of quickly accessible links.

Donald Boscoe

Good description of Clark's Giant Steel Fountain

Fireworks

Fireworks in UK: Where to buy, what to buy, shows calendar, history, photography, party page, glossary etc.

fireworks international

a very good platform for fireworks trade

Freakpyromaniacs

Freakpyromaniacs is a dutch pyrosite, since 1999/2000 the largest firework source on the net (in the benelux). Alot of video's/photo's and a (dutch) forum.

Harold Bentley

Nice rocket tooling

Inferno Labs

Site with many high quality videos and a growing number of tutorials.

Interactive Fireworks Applet

Create your own fireworks display by clicking your mouse on this java applet to launch computer generated shells.

Jackie Whedbee

Erotic fireworks pics?

Krimzonpyro.com

Rat_Bastard's site, including sections by him, DavidThePyro, EP, and Zero, all from the Totse Backyard Ballistics Forum.

Larry Crump

lots of pictures

Maxpowa

Contains info on tools, techniques and more.

Montreal Fireworks Competition Reports

Paul Marriott's website containing updated reports during the montreal fireworks competitions, plus a backlog of reports from past years. Very nice collection of photographs from various competitions. Well designed site.

Peter Mcmalley

ball mill pics

Petri Pikho's Pyro Page

basic intro, nice pictures

PyroFX.COM

A well designed site with user managed content. Excellent navigation scheme with lots of links and content.

PyroPlanet.com

The doorway into the fireworks world. Featuring world news, links, stories, events and a directory of pyrotechnicans.

PyroReview.com

The only interactive fireworks review site on the web! We also have a gallery with tons of 1.3g and 1.4g photos and videos, as well as a forum to discuss the world of fireworks.

Pyrosamm

picture of big honkin' girandola

Randy Alberts

'The Ultimate Star Pump'

Richard H's Pyro Page

A basic overview of pyrotechnics. Based in the UK.

Richard Nakka's Experimental Rocketry Web Site

This web site is to share experiences, ideas and details of experimental rocketry with others who have a similar interest. Very good collection of rocket related links on this site.

Stephen Ashley

Australian Fireworks

Steve Johnson's Pyro Page

The Green Man

English personal pyro page

Tom Smith

large pyro glossary

Toni Busuttil's WebSite

The man who first brought Maltese firework building techniques to the US now has his own website.

West Coast Pyrotechnics

Canadian pyro page

Wouter Visser's Practical Pyrotechnics

One of the better personal pyro pages. This one has a good deal of useful content and a rather extensive chemical dictionary.

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Links

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Catagories:

Pyro Clubs

ABCPyro - Pyrotechnie.org

The only French gate on pyrotechny, the fireworks. Post your definitions, photographs, your Curriculum vitae, dates of spectacles... A broad range of tools is proposed to you in order to share your knowledge pyrotechnics.

Artificiers Associés

French pyrotechnic club

Bluegrass Pyro Guild

Kentucky and neighboring states.

British Pyrotechnics Society

The BPS is the number one resource for pyro enthusiasts in the UK.

Canadian Fireworks Association

Our mission is to promote the safe and responsible use of both fireworks and pyrotechnics in Canada.

Canadian Pyro Guild

Connecticut Pyrotechnics Association

Established in 1986.

Crackerjacks

An active fireworks club in the Virginia, Pennsylvania, Maryland area.

Dublin University Pyrotechnics Society

aka, Flamers

Fireworks Magazine Online

Britain's only periodical for fireworks enthusiasts.

International Pyrotechnics Chat

IRC: #pyrotechnics Irc.chat4all.org: 6667 Java Applet: http://djc.tts.lt/ Chat with pyro's from all over the world.

Lily Fireworks Factory in Mqabba, Malta
A well designed website featuring one of the best known fireworks clubs in malta. Check out the pictures under the Fireworks Factory section!

Michigan Pyrotechnic Arts Guild
MPAG was incorporated in January, 1999.

Missouri Pyrotechnics Association
MoPyro's guild site with news, pictures and projects.

Northern Lighters
Pyro club in Minnesota.

Piroart.com
Not completely sure if this is a club, as the site is all in Spanish. Still some good fireworks pictures to look at even if you can't read Spanish.

Pyrotechnic Artists of Texas
aka, Fire Ants

Pyrotechnics Association of Tampere
Pyroteekkarit is a club of pyrotechnics enthusiasts that study or work at the Tampere University of Technology, Tampere, Finland.

Pyrotechnics Guild International
The largest pyrotechnics guild in the world. The PGI convention is held every year in August, usually in the Northern US.

R-BP
Email based group for BP Rocket enthusiasts

Rocky Mountain Pyrotechnics Guild
Colorado guild page with good links. Great pics of Maltese shells: click pyro-pages, then Toni's Irdieden to get to the Maltese picture links.

Skyrockers
Volunteer organization that performs fireworks shows as a community service in the La Crosse, Wisconsin.

Western New York Pyrotechnic Association
Formed in October of 1992. Nice web page.

Western Pyrotechnics Association
Home of the Western Winter Blast

Wisconsin Pyrotechnic Arts Guild
WPAG holds at least four meetings/shoots a year in various locations in Wisconsin.

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Catagories:

Pyro Photography

123Greetings.Com - Chinese New Year Fireworks Greeting Cards

Chinese New Year is the perfect time to have a blast with all the people you love. Spread the spirit of celebration all round with our crackling Chinese New Year Fireworks ecards. Send Chinese Roman Candles, Chinese Spinning Wheels, Chinese Parachutes and Rockets through our exiting range of Chinese New Year ecards. Here’s wishing you a New Year that’s a blast of fun !

Burch Communications

Nice fireworks pictures

California Photographer

Tips on photographing pyro

Dimock's 1996 PGI photos

Japanese Symposium

Some nice pics from a Japanese convention show

Maltese Fireworks Pictures

Good collection of Maltese fireworks pictures

Maltese Irdieden (wheels)

All about the art of the beauty of the Maltese Irdieden

Montreal Fireworks Competition Photos

This is one really nice collection of fireworks photographs!

Photographing Fireworks

Tips on how to take better pictures of pyro

Pyro Pictures Dot Com

Lots of good pictures from conventions around the world.

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Catagories:

Rockets

DJ's Nozzeless BP Rockets

pics and tool specs for 1lb nozzeless rockets.

Jetex Information

Links for micro-jet enthusiasts.

Stanford Systems Aerospace Division

Amateur rocketry articles, tutorials, downloads, supplies and lots of other info.

Static Rocket Motor Tests

Photos and videos of rocket engine tests by the Flemish Rocket Organisation. Engine types include H2O2/Petroleum, PVC/KNO3, AP/HTPB/AL, KNO3 and Zinc/Sulfur.

Underwater Rockets

Information about launching model rockets from the bottom of lakes in depths up to 100 feet!

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MILLING MEDIA: 3/4" X 3/4" Cylindrical Ceramic Milling Media for sale. Mills powerful homemade "meal powder" in a fraction of the time that balls do. Mine show LITTLE to NO WEAR after over 300 milling runs. Even mills Barium Nitrate quickly and with ease. Don't contaminate Your chemicals or mixtures with lead!

FYI, a one gallon container holds roughly 12 lbs to make it half full, which is optimal.

Available in 25 or 50 lb bag increments only. Price is $2.95/lb delivered to the convention in Fargo, ND in 2007. The price will be higher to ship to your location, obviously. Contact me for more information:

jharmon12@juno.com

Phone: 402-291-7544

1/2, 3/4, & 1 Inch Cardboard tubes.

Rock hard spiral wound tubes with 1/8 wall work great for Rockets Gerbs, & even Whistle. Satisfaction Guaranteed.

Firework PROFESSIONALS LTD

Firework Professionals Ltd

Firework Show Performers, Fireworks Suppliers. Firework Manufactures. Special Effects, Proximate Pyro and Industrial Pyro.

Website

Phone: 64-03-982-3473
Fax: 64-03-982-3474

Help fight off the CPSC & protect fireworks!

The Fireworks Foundation is an organization devoted to the preservation of the fireworks hobby. This is a non-profit organization, and donations are accepted online.

Please help. Every little bit counts in this and future battles.

Website

Indian Blackhead Aluminum For Sale

I am currently selling Indian Blackhead Aluminum for $ 18.00 a pound + $ 7.00 for Shipping on the first pound. This is the best aluminum I have seen in years. It is imported directly from India for use in pyrotechnics.

Please Email me directly with your Zipcode name and phone number for orders over 1 Pound. I will the send you a quote including the shipping. My

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Website

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Pyro-RIGHT laboratory grade multipurpose Heating Mantles, NiChrome Wire, Temp Controllers, Lead Molds for grinding medium, etc. Monthly sales.

Website

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Fax: (606) 365-2925

ProFormance Pyrotechincs Ltd

ProFormance Pyrotechnics is an industry leader providing the world with the availability of choice and brilliance, from firing systems, to customized effects, international wholesale and supply, ProFormance Pyrotechnics holds the answer to all your effect and firing requirements.

Website

Phone: +61 3 5940 1555
Fax: +61 3 5941 4743

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8" samples are available for evaluation.

Website

48" Virgin Kraft Rolls

I have the following weights of virgin kraft paper for sale. Tested and approved by experienced pyrotechnists.

40# (app. 1035 lineal feet) - $60.00
60# (app. 720 lineal feet) - $60.00
70# (app. 565 lineal feet) - $50.00
80# (app. 513 lineal feet) - $50.00

I can deliver to Fargo in August 2007. Otherwise, shipping is additional and will be actual cost via USPS from Missoula, Montana to your location. Please email for samples (n/c) or more info:

tkolwicz@bresnan.net

Phone: 406-542-4255

Amateur Pyrotechnics & Chemistry Forum

Dedicated to spreading knowledge of pyrotechnics and related subjects through discussion and cooperation while promoting safety and responsibility. Our community is constantly growing and evolving so take a look, stay a while, and enjoy yourself. Please read the rules and FAQ before posting. Join today! Registration is free.

Website

American Fireworks News

Supplier of fireworks literature including books, how-to manuals, videos, newsletters and trade directories.

Website

Phone: (570) 828-8417
Fax: (570) 828-8695

email address is as follows:
skypainter133@yahoo.com

When you purchase the aluminum, payment thru Paypal is prefered.

Thank You,

Skypainter

KNJ Printers Supply

Wheat paste fast delivery
Call for price
875 Gray St
Columbus, Ohio 43201
1-800-875-6331
Attn: Blair

Phone: 1-800-875-6331
Fax: 614-294-8885

kno3.co.uk

Finally a uk based supplier of potassium nitrate and other pyro chemicals at a cheap price!

kno3 from just £5 per 500 grams!

Website

Phone: 07906211913

Liu yang Flying Dragon Fireworks & Northern Star Pyrotechnics

If you want only the very best in fireworks and supplys, we can do it. We export around the world. With offices in the USA, Spain, and China. We can do it all, in one stop. Let us show you around next time you are in China. Quality is only the best.

Website

Phone: 507-245-5132
Fax: +860731-3679849

Liuyang Flying Dragon Fireworks Co; Ltd.

EXPORT Consulation If you want it We can get it. We handle both 1.3 and 1.4 fireworks, Exported to you at the best factory prices. Let us do the leg work for you. Desige, Evaluation, Improvement, Testing & Quality Control. When only the best will do. Your Personal Agent In China

Website

Phone: +86-13637485808

Pyro toolings ,fireworks from China

I am selling fireworks,pyro tools,firing systerms,parts for E-match and paper ball shell casings from China at very good prices.
Please contact me for more infomation at supremepyro@yahoo.com.cn

Website

Pyro tools with Stainless spindles

We are an affordable supplier of pyro tooling that have stainless spindles . We have whistle , strobe , black powder rocket sets , as well as fountain tooling and star guns .

Website

Phone: 928-201-3131

PyroMotion Choreography Software

Choreography software that is easier and more fun to use! Use a timeline to drag and drop fireworks then export voice cues and setup sheets at the press of a button!
Low cost lease!

Website

Phone: 519-942-9339
Fax: 519-942-8572

PyroPlanet.com

The doorway into the world of fireworks. Find the latest News, Events, Stories, and people!

Website

Phone: 519-942-9339
Fax: 519-942-8572

PyroSupplies.Com

A leading supplier of high quality and hard to find pyrotechnic supplies. Offers an amazing collection of high quality paper and string, including the hard-to-find single ply jute twine used

Bell's Fireworks

Bell's fireworks provides the Central Florida Area with the finest quality consumer fireworks there are. We carry a wide range of all types of consumer fireworks from sparklers to firecrackers and re-loadable shells.

Website

Phone: (813) 935-8810
Fax: (813) 933-8536

Blackpowder Manufacture

90 minute video with a 30 minute tour of Hagley Museum, site of the Dupont powder works on the Brandywine River. $12.00 PP

Paulownia charcoal, the best for black powder manufacture: $2.50 lb. (powdered) made from debarked wood. Can not ship. Call and make arrangements to pick up or I will deliver to meetings, etc.

Stan Williams
4117 Grand Ave
Sebring, Fl 33872
cell phone: (863) 414-2083

Phone: (863) 385-2351

Class C consumer fireworks shipped to your door!

Apollo fireworks stocks 100 different class c items available for easy and hassle free mail ordering. Our website/online store is easy to use and has a picture for every item. We encourage you to call anytime with questions or for recommendations. For those wishing to start a fireworks business, check out our tent package.

Website

Phone: 603-556-3208

Fax: +86731-3679849

Magic-Fire Pine Cones

Leelanau Magic Fire Pinecones

Make your fire dance with colors in blue and green. Magic-Fire Pine Cones are a real treat for anyone who has a fireplace or campfire that burns wood. Each cone lasts for half an hour giving the fire magic dancing colors.

two bags of 4 cones for $12 plus $4 s/h
you can get them at Jaffe's in the town of Lake Leelanau or from me.

contact: woodbeevans@aol.com

MONETTI s.r.l.

PYROLEDA® firing system, PYROCLOCK® pyrotechnics delay,SHOWSIM european distributor,PYROLEDA® firing sistem for hire,technical assistance and choreography development.

Monetti Srl’s professional technicians are available to provide a complete show assistance (from choreography to show set up).
If you’re interested in purchasing PYROLEDA® products but feel unsure about using them for the first time,or if you need assistance in managing an important show, Monetti Srl’s professional technicians can help you on-site and guarantee 100% the success of your show.

Website

Phone: +39 0564 860877
Fax: +39 0564 867734

NITROPARIS

Spanish firework chemical supplier. Very cheap chemicals, and very fast delivering.

Potassium Perchlorate $ 2.30 1000g

Website

Phone: +34 964 67 39 27
Fax: +34 964 67 49 84

ODA Enterprises Introduces... Q-Fire!

The easiest, most affordable

to make maltese shells. Also a great source for bulk wheat paste and hot glue sticks for every type of applicatoin.

Website

Phone: (877) 770-5500
Fax: (727) 669-0700

PyroTube.com

We sell tubes for pyrotechnics and specialize in high quality reasonably priced tubes and some other odds and ends, our product line is always expanding. Quality, price and customer service. Ship world wide too.

The website below me (literally below me, in all meanings of the word) is not affiliated with PyroTube.com nor endorsed by PyroTube.com. Basically he just ripped off my name.

Website

PyroTubes.com

We are here to offer you an alternative to the other guys out there. We stand by our customer service 100% If your not happy with what you ordered, just let us know and we will make it right! All orders go out of here with tracking numbers so theres no guessing on when your order will get there!

We Offer A wide range of Tubes sizes and are adding more every day! Come check out our Quick Visco and our other Fuses!

Website

UK pyro tube supplier

1/4 inch ID, 3/4 inch ID, 1 inch ID parallel/convolute tubes in the UK and will send just about anywhere.
All tubes are very strong (strongest i have ever seen) with totally rock solid thick walls. The thinnest wall sold is 2 mm which is on the 1/4 inch ID tubes, the 1 inch ID tubes have super thick walls of 7mm!

More sizes on their way soon!

Website

E-match heads with Pyrogen
Make your own E-matches by just soldering twin lead wire to our E-match heads. As low as 12 cents each. For more info go to our web site.

Website

Choreography/Scripting/Firing system on the market. For a demo CD, send $10 ppd (fully refundable with purchase of Q-fire) to:

Octavio Aguiar
5072 Strafford Oaks Drive
Sebring, FL 33875

PayPal orders:
email octavioag@comcast.net

Website

Mail Passfire.com

Links

This is a collection of links to all things pyrotechnical on the internet. If there are any sites that you like and they are not listed here, you can help make this list more complete by adding a link yourself.

Catagories:

Suppliers

ACE Enterprises

Welcome to the new ACE Pyro web site! We offer a variety of products and services to pyrotechnicians and fans of fireworks. Featuring: Acculab balances, pyrotechnic chemicals, and display fireworks choreography & show design.

ACME Spirally Wound Paper Products, Inc.

Acme Spiral manufactures paper tubes & cores in a variety of sizes and wall thicknesses. Marketed for use as mailing tubes, but other uses come to mind.

Advanced Technique Fireworks, Inc.

Display Fireworks Equipment Manufacturers & Distributor BATF Licensing: Manufacturer Display Fireworks Importer Display Fireworks No sales of 1.3g without BATF License

American Fireworks News

Supplier of fireworks literature including books, how-to manuals, videos, newsletters and trade directories.

Atlas Pyrovision Productions

We are Atlas PyroVision Productions, a leader in pyrotechnic displays and display design. We ensure that every one of our 700 yearly performances is an innovative blend of science and delight!

Axner Company

This is actually a pottery supply company, but they have a number of chemicals and some clays that pyros can utilize.

Bell's Fireworks Co.

Full selection of consumer fireworks as well as display fireworks and materials.

Colonial Gun Works and Supplies

Cheap lead milling media

Coonie's Black Powder

Supplier of Goex black powder, thermalite, sticky match, DaveyFire igniters, visco etc..

CoorsTek
Makers of ceramic milling media, among other things.

Custom Pyrotechnics
Chemicals and supplies.

Dawntreader Pyrotechnic Specialites
Cark's Giant Fountain tooling, rocket tooling (Wolter-made), specialty chemicals.

Delcor Industries Inc.
Manufacturer of firing panels for all types of displays.

Discount Pyro
Very cheap supplier of chemicals, plastic shell and salute parts, paper parts, etc...

Edmund Scientific
Supplier of educational sciene related projects, lab supplies, telescopes etc. Can order from online store link below.

F.P. Engbert Discount Guns
Supplier of mortar tubes and racks

Firefox Enterprises Inc.
Chemicals and pyrotechnic supplies for the hobbiest.

Firework Events
Firework displays and sales......

Firework Professionals Ltd
Firework Show Performers, Fireworks Suppliers. Firework Manufactures. Special Effects, Proximate Pyro and Industrial Pyro.

Fireworks International
Fireworks International offers a large range of DIY Fireworks Packs and Single Ignitions to Buy Online. And our Display Team also provides spectacular Operator Fired Firework Displays.

FireworksExpress.com
Shop at anyone of our nationwide retail outlets, all offering special savings to online shoppers. Fireworks for personal use or for business needs. Individuals, Retailers, Wholesalers, and Parties interested in Consumer Fireworks and/or Professional Displays can be served on our website.

foodservicedirect.com
Supplier of coffee filter paper that may be used for applications that require gampi tissue. Search on "coffee filter" from the home page.

Goex
One of few manufacturers of black powder supplying North America, in business since 1912.

Granite Falls Arts Inc.
More commonly known as "Rich Wolter Pyro Tools," maker of some of the best pyro tools around. Supplying the professional and hobby industry since 1973.

Hawk Mountain Enterprises
A supplier of large scale rocket kits. Also a cheap source for atomozed and 325m flake aluminum.

HB Rocket Tooling

Harold Bentley makes good quality inexpensive rocket tooling. He also makes the P2F gauge, a device that measures the actual force being applied when pressing rockets, which saves you the trouble of mathematically converting the PSI on a bottle jack gauge to actual force applied! There are two types - one is portable from press to press, the other is designed to be mounted permanently to your press. They're available in 0- 5,000 and 0- 10,000 ranges.

Hobby Fireworks L.L.C.

Ball mills, milling media, star rollers and rocket presses.

Hummel Croton Inc.

Wholesale chemical supplier of just about everything you would ever need. This is not a hobby supplier, so you have to order big quanities and pay freight shipping. This is one of the suppliers for commercial manufacturers.

Iowa Pyro Supply

Pyro chemicals and supplies for the hobby enthusiast and professionals. Competitive prices in the small-quantity pyro chemical market. Also has among the best low-volume prices for kraft end disks.

Journal of Pyrotechnics, Inc.

Pyrotechnic reference series.

Kastner Pyro Supply

Plastic and paper supplies. Catalog $1

Kellner's Fireworks Inc.

Kellner's Fireworks is a direct importer of Consumer, Display and Close Proximity Products. Kellner's provides FREE DELIVERY to FPAG Spring Shoot and Fall Fest. Consumer products are at a 50% discount from list for FPAG and PGI members.

LeMark Group

Le Mark manufacture a range of both high heat resisting(BlackTak)matt black foil. Custom self-adhesive fixings for 'gerbs'and Flame Retardent Cloth Gaffer tapes for the Pyrotechnic Industry Professionals

Liquid Sunshine/ globalgatherings.com

Sells hemp twine for a reasonable price.

Liuyang bingshan trading co., Ltd

supplier of premium fireworks in the fireworks town of china

Liuyang Rising Fireworks Co., Ltd.

very slow site load time

Lortone Inc.

Maker of rock tumblers commonly used as ball mills.

McMaster Carr

Mail order supplier of over 390,000 products such as pipes, raw materials, motors, bearings, fastners, hand tools, machine and many screens of all different mesh sizes made from brass, stainless, aluminum etc. Excellent website makes finding stuff easy.

MECI

MECI (Mendelson Electronics Company Inc) sells surplus electronic and electromechanical equipment. Great source for cheap motors of all sizes and speeds. Website makes searching for stuff easy.

Mighty-Mite Marketing Inc.

Manufacturer of 100% High Density Polyethylene (HDPE) one piece fireworks mortars. Mighty-Mites come in 2" (50mm), 2 1/2" (60mm), 3" (76mm) and 4" (102mm) inside diameters. Also sells Pyro-Pipe Mortars in 5" (127mm), 6" (155mm) and 8" (205mm) IDs from custom extruded HDPE pipe and a solid wood plug, which is fastened with bolts all the way through.

Monetti s.r.l.

Pyroleda digital firing system suppliers ,David Bickford electric ignitors and PYROCLOCK® distributor.

Next F/X

Great special effects (close proximity pyrotechnic effects) supplier

Northwest Charcoal

Good source of bulk charcoal in different mesh sizes.

ODA Enterprises

Manufacturer of affordable electrical firing equipment - for the hobbyist or pro.

Patriotic Fireworks

Manufacturer & Distributor of a wide variety of fireworks including smoke bombs, fire crackers and sky rockets.

Platte River Fireworks Inc.

Display operator and Class B & C sales. Also carries mortars, finale racks, wood plugs, paper disks etc.

Precocious Pyrotechnics, Inc.

A primary manufacturer of display fireworks and pyrotechnic special effects. One of the few US manufacturers that still make traditional Italian-American style shells. Also supplies the same specialty paper and other goods used in making their products such as casings, cans, disks and twine to manufacturers and enthusiasts alike. One of few suppliers for high-quality Japanese hemis.

Pyro Novelties, Inc.

Pyro Novelties Inc. is your source for fireworks-related apparel and gift merchandise. Online store features: T-shirts, hats, pyro accessories and safety gear for the pyrotechnic lifestyle.

Pyro Plastics Inc

Manufacturer of plastic ball shells, canisters, mortar bases etc. They sell direct at lower prices than can be found through typical resellers.

Pyrocentral

Very cheap prices on various chemicals.

Pyrocreations.com

We are a fairly new company. 1 1/2 years. We are proud to offer products to make your own fireworks and other pyrotechnic products at the lowest prices on the net. We keep close whatch to all other sites that sell the same products and make sure we WILL beat there price on most of our products. We have doubled our stock within the past year and hope we can tripple it by this time next year.

Pyrohouse.com

MFG and supplier of HDPE tubes, racks and supplies.

Pyromate Inc.

Manufactures some of the world's finest professional electronic firing systems in the pyrothenics industry.

Pyroshot

Manufacture electrical firing systems. Made in Australia.

PyroSupplies.com

A leading supplier of high quality and hard to find pyrotechnic supplies. Offers an amazing collection of high quality paper and string, including the hard-to-find single ply jute twine used to make maltese shells. Also a great source for bulk wheat paste and hot glue sticks for every type of applicatoin.

Pyrotek Inc.

Chemicals, acids, solvents, labware.

PyroTooling.com

We are an affordable supplier of Pyro tools and all our spindles are made of Stainless Steel

PyroTube.com

Sells 1/4" inside diameter, 2" long, 1/16" wall tubes that have a gloss red wrap and other products. Tubes are good for making bottle rockets, shell inserts, go getters and so on. Ships World wide.

Rice Hull Supplier (Presque Isle)

This is actually a wine making supply company, but they sell 50lb bags of rice hulls for $11.50 and you can order online.

Rising Fireworks Co.,Ltd

We supply various kinds of Fireworks such as consumer fireworks and display fireworks: 2~{!1~}-16~{!1~} Display Shells, Cakes, Roman Candles, Firecrackers, Fountains, Rockets, Spinners, Wheels, Sparklers, Parachutes, Smokeless Fireworks, etc.

Santore & Sons Inc.

Manufacturer of a full line of close proximity / indoor pyrotechnics. Please call / e-mail for a current catalog. Satisfaction of all products guaranteed.

Sky Canvas Designs

Source for pyrotechnic graphics, posters, live limited edition firecrackers and beautiful inert shells to use as training aids, etc. Will do custom art work to your specifications.

Skylighter, Inc.

Stocks nearly everything needed by the pyro hobbyist, including the largest selection of chemicals of any small-quantity hobby dealer. Also a source for all the popular literature and some paper items.

Standford System Areospace Division

Chemicals, motors, supplies, instructions, electronics, kits and everything having to do with amateur rocketry. NOTE: some customers report problems receiving their orders from this company, and it also has an unsatisfactory rating with the BBB of Az.

Superior Fireworks

U.S. Plastic Corp.

Supplier of large variety of plastic containers, scoops, lab ware, spritzers, stock material, drums, vats and just about any kind of industrial equipment made of plastic.

Westwood Supply Co.

Chemicals and visco fuse.

Mail Passfire.com

PASSFIRE.COM

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Home Archives Formulas Reference Market Forum ShowSim Help

PYROTECHNIC RESOURCES

- Chemical Dictionary
- Calculators
- Tables
- Literature
- Suppliers
- Links

Links

This is a collection of links to all things pyrotechnical on the internet. If there are any sites that you like and they are not listed here, you can help make this list more complete by adding a link yourself.

Catagories:

Technical Info

BP Die Design Calculator

A simple interactive calculator for figuring out powder die parameters for specific densities. All calculations in metric units.

Chemixtry Startpage (Dutch)

Information on chemistry & pyrotechnics startpage (dutch)

Feuerwerk.net

A well designed German fireworks site with lots of pictures and even some animations. The header reads "The information portal for fireworkers and fireworks fans." All text is in German.

Humidity and Black Powder

Illustrated Pyro Glossary

A nice glossary page with pictures and cross reference links.

Irdieden Website

A nice site with lots of pictures and information about Maltese wheels (irdieden). Even includes a calendar showing the various festivals for all the towns.

JAPANESE FIREWORKS

Infomation of Japanese fireworks

Maltese Fireworks Construction Photos

Some good close-ups of Maltese shells under construction.

Mesh to Micron Conversions

US Mesh size to Micron conversion table

Paulownia Tree Info

Everything you want to know about this prized charcoal making tree.

Pyro Universe

Lots of pyro related information and links, including a calendar, glossary, chat board (w/popup pollution), "you might be a pyro if.." collection, projects and more.

PyroReview.com

This is a site that provides good information on the quality and performance of Class C items. There's a forum attached to each item so that you can read what other people thought of it. Sort of like amazon.com but applied to fireworks instead of books. If you register you can also view pictures and videos of products in action. Very cool!

Pyrotechnic Chemical Dictionary

Chemical dictionary on the United Nuclear site.

Pyrotechnic Formula Page (PFP)

The first extensive online database for pyrotechnic formulas.

Pyrotechnic Glossary

A basic glossary of pyrotechnic terms.

Tom Peregrin

Archived version of an old favourite

Visual Catalog of Japanese Fireworks

Look up the correct name for an effect, or get new ideas. Lots of pictures!

WWII German Military Pyrotechnics

The Chemical Compositions of German Pyrotechnic Colored Signal Items.
Reported by: Mr.Henry J. Eppig U.S. Ord June - August 1945

Mail Passfire.com

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Catagories:

Tools

fireworks international

a firework platform in chinese

Fireworks Making Machines

We sell Star Roller, Ball Mills, Rocket Presses, Star Size Separators and Hardened Lead Media.

French Pyrotechnic Forum

French Pyrotechnic Forum

Granite Falls Arts Inc.

More commonly known as "Rich Wolter Pyro Tools," maker of some of the best pyro tools around. Supplying the professional and hobby industry since 1973.

Kastner Pyroechnics & Fireworks Mfr. Co., Inc.

Great source for quality HDPE Mortars & Racks--especially like the racks for artillery shells!

Lortone Rock Tumblers

Popular rock tumbler for converting to a ball mill.

Planetpyro.com / Pyroplanet.co.uk

Supplier of Visco Fuse, Falling Leaf fuse, Flying Fish fuse, tubes, shells and more to the pyrotechnic community.

Richard and Claudia Wolter

Pyrotechnic tooling

Thunder and Lightening Tools

Comet pumps, rocket spindles, case formers etc.